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(54) Title: PREVENTION AND TREATMENT OF AMYLOIDOGENIC DISEASE

(57) Abstract

The invention provides compositions and methods for treatment of amyloidogenic diseases. Such methods entail administering an agent that induces a beneficial immune response against an amyloid deposit in the patient. The methods are particularly useful for prophylactic and therapeutic treatment of Alzheimer's disease. In such methods, a suitable agent is Aβ peptide or an antibody thereto.

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PREVENTION AND TREATMENT OF AMYLOIDOGENIC DISEASE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application derives priority from USSN 60/067,740, filed December 2, 1997, and USSN 60/080,970, filed April 7, 1998, which are incorporated by reference in their entirety for all purposes.

TECHNICAL FIELD

The invention resides in the technical fields of immunology and medicine.

BACKGROUND

Alzheimer's disease (AD) is a progressive disease resulting in senile dementia. *See generally* Selkoe, *TINS* 16, 403-409 (1993); Hardy et al., WO 92/13069; Selkoe, *J. Neuropathol. Exp. Neurol.* 53, 438-447 (1994); Duff et al., *Nature* 373, 476-477 (1995); Games et al., *Nature* 373, 523 (1995). Broadly speaking the disease falls into two categories: late onset, which occurs in old age (65 + years) and early onset, which develops well before the senile period, i.e, between 35 and 60 years. In both types of disease, the pathology is the same but the abnormalities tend to be more severe and widespread in [illegible] plaques and neurofibrillary [illegible]

[illegible] consisting of [illegible] in pairs.

The principal constituent of the plaques is a peptide termed Aβ or β-amyloid peptide. Aβ peptide is an internal fragment of 39-43 amino acids of a precursor protein termed amyloid precursor protein (APP). Several mutations within the APP protein have been correlated with the presence of Alzheimer's disease. See, e.g., Goate et al., *Nature* 349, 704) (1991) (valine^{717} to isoleucine); Chartier Harlan et al. *Nature* 353, 844 (1991)) (valine^{717} to glycine); Murrell et al., *Science* 254, 97 (1991) (valine^{717} to phenylalanine); Mullan et al., *Nature Genet*. 1, 345 (1992) (a double mutation changing lysine^{595}-methionine^{596} to asparagine^{595}-leucine^{596}). Such mutations are thought to cause Alzheimer's disease by increased or altered processing of APP to Aβ, particularly processing of APP to increased amounts of the long form of Aβ (i.e., Aβ1-42 and Aβ1-43). Mutations in other genes, such as the presenilin genes, PS1 and PS2, are thought indirectly to affect processing of APP to generate increased amounts of long form Aβ (see Hardy, *TINS* 20, 154 (1997)). These observations indicate that Aβ, and particularly its long form, is a causative element in Alzheimer's disease.

McMichael, EP 526,511, proposes administration of homeopathic dosages (less than or equal to 10^{-2} mg/day) of Aβ to patients with preestablished AD. In a typical human with about 5 liters of plasma, even the upper limit of this dosage would be expected to generate a concentration of no more than 2 pg/ml. The normal concentration of Aβ in human plasma is typically in the range of 50-200 pg/ml (Seubert et al., *Nature* 359, 325-327 (1992)). Because EP 526,511's proposed dosage would barely alter the level of endogenous circulati[illegible]

[illegible] implaus[illegible]

By contrast, [illegible]

[illegible] therapeutic regimes for [illegible] the neuropathology of Alzheimer's disease.

SUMMARY OF THE CLAIMED INVENTION

In one aspect, the invention provides methods of preventing or treating a disease characterized by amyloid deposition in a patient. Such methods entail inducing an immune response against a peptide component of an amyloid deposit in the patient. Such induction can be active by administration of an immunogen or passive by administration of an antibody or an active fragment or derivative of the antibody. In some patients, the amyloid deposit is aggregated Aβ peptide and the disease is Alzheimer's disease. In some methods, the patient is asymptomatic. In some methods, the patient is under 50 years of age. In some methods, the patient has inherited risk factors indicating susceptibility to Alzheimer's disease. Such risk factors include variant alleles in presenilin gene PS1 or PS2 and variant forms of APP. In other methods, the patient has no known risk factors for Alzheimer's disease.

For treatment of patients suffering from Alzheimer's disease, one treatment regime entails administering a dose of Aβ peptide to the patient to induce the immune response. In some methods, the Aβ peptide is administered with an adjuvant that enhances the immune response to the Aβ peptide. In some methods, the adjuvant is alum. In some methods, the adjuvant is MPL. The dose of Aβ peptide administered to the patient is typically at least 1 or 10 μg, if administered with adjuvant, and at least 50 μg if administered without adjuvant. In some methods, the dose is at least 100 μg.

In some methods, the Aβ peptide is Aβ1-42. In some [illegible]

[illegible] effect [illegible]

[illegible] through the [illegible] some methods, a therapeutic agent is identified by screening a

library of compounds to identify a compound reactive with antibodies to Aβ, and administering the compound to the patient to induce the immune response.

In some methods, the immune response is directed to aggregated Aβ peptide without being directed to dissociated Aβ peptide. For example, the immune response can comprise antibodies that bind to aggregated Aβ peptide without binding to dissociated Aβ peptide. In some methods, the immune response comprises T-cells that bind to Aβ complexed with MCH1 or MHCII on CD8 or CD4 cells. In other methods, the immune response is induced by administering an antibody to Aβ to the patient. In some methods, the immune response is induced by removing T-cells from the patient, contacting the T-cells with Aβ peptide under conditions in which the T-cells are primed, and replacing the T-cells in the patient.

The therapeutic agent is typically administered orally, intranasally, intradermally, subcutaneously, intramuscularly, topically or intravenously. In some methods, the patient is monitored followed administration to assess the immune response. If the monitoring indicates a reduction of the immune response over time, the patient can be given one or more further doses of the agent.

In another aspect, the invention provides pharmaceutical compositions comprising Aβ and an excipient suitable for oral and other routes of administration. The invention also provides pharmaceutical compositions comprising an agent effective to induce an immunogenic response against Aβ in a patient, and a pharmaceutically acceptable adjuvant. In some [illegible]

[illegible]

patient and, [illegible]

example, the conjugate can serve to promote an immune response

against Aβ. In some compositions, the conjugate is cholera toxin. In some compositions, the conjugate is an immunoglobulin. In some compositions, the conjugate is attenuated diphtheria toxin CRM 197 (Gupta, *Vaccine* 15, 1341-3 (1997).

The invention also provides pharmaceutical compositions comprising an agent effect to induce an immunogenic response against Aβ in a patient with the proviso that the composition is free of Complete Freund's adjuvant. The invention also provides compositions comprising a viral vector encoding Aβ or a an active fragment thereof effective to induce an immune response against Aβ. Suitable viral vectors include herpes, adenovirus, adenoassociated virus, a retrovirus, sindbis, semiliki forest virus, vaccinia or avian pox.

The invention further provides methods of preventing or treating Alzheimer's disease. In such methods, an effective dose of Aβ peptide is administered to a patient. The invention further provides for the use of Aβ, or an antibody thereto, in the manufacture of a medicament for prevention or treatment of Alzheimer's disease.

In another aspect, the invention provides methods of assessing efficacy of an Alzheimer's treatment method in a patient. In these methods, a baseline amount of antibody specific for Aβ peptide is determined in a tissue sample from the patient before treatment with an agent. An amount of antibody specific for Aβ peptide in the tissue sample from the patient after treatment with the agent is compared to the baseline amount of Aβ peptide-specific antibody. An amount of Aβ peptide-specific antibody [illegible]

[illegible]

subject after treatment with the agent is compared to the

baseline amount of Aβ peptide-specific antibody. A reduction or lack of significant difference between the amount of Aβ peptide-specific antibody measured after the treatment compared to the baseline amount of Aβ peptide-specific antibody indicates a negative treatment outcome.

In other methods of assessing efficacy of an Alzheimer's disease treatment method in a patient a control amount of antibody specific for Aβ peptide is determined in tissue samples from a control population. An amount of antibody specific for Aβ peptide in a tissue sample from the patient after administering an agent is compared to the control amount of Aβ peptide-specific antibody. An amount of Aβ peptide-specific antibody measured after the treatment that is significantly greater than the control amount of Aβ peptide-specific antibody indicates a positive treatment outcome.

In other methods of assessing efficacy of an Alzheimer's treatment method in a patient, a control amount of antibody specific for Aβ peptide in tissues samples from a control population is determined. An amount of antibody specific for Aβ peptide in a tissue sample from the patient after administering an agent is compared to the control amount of Aβ peptide-specific antibody. A lack of significant difference between the amount of Aβ peptide-specific antibody measured after beginning said treatment compared to the control amount of Aβ peptide-specific antibody indicates a negative treatment outcome.

Other methods of monitoring Alzheimer's disease or [illegible] nt. [illegible] ls, [illegible] zed an agent effective to treat [illegible] and th [illegible]

[illegible]
patient who has been treated with an agent is determined. The

value is compared with a control value determined from a population of patient experiencing amelioriation of, or freedom from, symptoms of Alzheimer's disease due to treatment with the agent. A value in the patient at least equal to the control value indicates a positive response to treatment.

The invention further provides diagnostic kits for performing the above methods. Such kits typically include a reagent that specifically binds to antibodies to Aβ or which stimulates proliferation of T-cells reactive with Aβ.

BRIEF DESCRIPTION OF THE FIGURES

Fig. 1: Antibody titer after injection of transgenic mice with Aβ1-42.

Fig. 2: Amyloid burden in the hippocampus. The percentage of the area of the hippocampal region occupied by amyloid plaques, defined by reactivity with the Aβ-specific mAβ 3D6, was determined by computer-assisted quantitative image analysis of immunoreacted brain sections. The values for individual mice are shown sorted by treatment group. The horizontal line for each grouping indicates the median value of the distribution.

Fig 3: Neuritic dystrophy in the hippocampus. The percentage of the area of the hippocampal region occupied by dystrophic neurites, defined by their reactivity with the human APP-specific mAβ 8E5, was determined by quantitative computer-assisted image analysis of immunoreacted brain sections. The values for individual mice are shown for the AN1792-treated group and the PBS-treated control group. The [illegible]

[illegible]

percentage [illegible] the area of [illegible] glial [illegible] acidic [illegible] positive [illegible]

[illegible] are indicated by horizontal [illegible]

Fig. 5: Geometric mean antibody titers to Aβ1-42 following immunization with a range of eight doses of AN1792 containing 0.14, 0.4, 1.2, 3.7, 11, 33, 100, or 300 μg.

Fig. 6: Kinetics of antibody response to AN1792 immunization. Titers are expressed as geometric means of values for the 6 animals in each group.

Fig. 7: Quantitative image analysis of the cortical amyloid burden in PBS- and AN1792-treated mice.

Fig. 8: Quantitative image analysis of the neuritic plaque burden in PBS- and AN1792-treated mice.

Fig. 9: Quantitative image analysis of the percent of the retrosplenial cortex occupied by astrocytosis in PBS- and AN1792-treated mice.

Fig. 10: Lymphocyte Proliferation Assay on spleen cells from AN1792-treated (upper panel) or PBS-treated (lower panel).

Fig. 11: Total Aβ levels in the cortex. A scatterplot of individual Aβ profiles in mice immunized with Aβ or APP derivatives combined with Freund's adjuvant.

Fig. 12: Amyloid burden in the cortex was determined by quantitative image analysis of immunoreacted brain sections for mice immunized with the Aβ peptide conjugates Aβ1-5, Aβ1-12, and Aβ13-28; the full length Aβ aggregates AN1792 (Aβ1-42) and AN1528 (Aβ1-40) and the PBS-treated control group.

Fig. 13: Geometric mean titers of Aβ-specific antibody for groups of mice immunized with Aβ or APP derivatives combined with Freund's adjuvant.

Fig. 14: Geometric mean titers of Aβ-specific antibody for [illegible]

Fig. 15: Aβ levels [illegible] the cortex [illegible] mice treated with AN1792 or AN1528 with different adjuvants.

[illegible] "substantial identity" means that two peptide sequences, when optimally aligned, such as by the programs GAP or BESTFIT using default gap weights, share at least 65

percent sequence identity, preferably at least 80 or 90 percent sequence identity, more preferably at least 95 percent sequence identity or more (*e.g.*, 99 percent sequence identity or higher). Preferably, residue positions which are not identical differ by conservative amino acid substitutions.

For sequence comparison, typically one sequence acts as a reference sequence, to which test sequences are compared. When using a sequence comparison algorithm, test and reference sequences are input into a computer, subsequence coordinates are designated, if necessary, and sequence algorithm program parameters are designated. The sequence comparison algorithm then calculates the percent sequence identity for the test sequence(s) relative to the reference sequence, based on the designated program parameters.

Optimal alignment of sequences for comparison can be conducted, e.g., by the local homology algorithm of Smith & Waterman, *Adv. Appl. Math.* 2:482 (1981), by the homology alignment algorithm of Needleman & Wunsch, *J. Mol. Biol.* 48:443 (1970), by the search for similarity method of Pearson & Lipman, *Proc. Nat'l. Acad. Sci. USA* 85:2444 (1988), by computerized implementations of these algorithms (GAP, BESTFIT, FASTA, and TFASTA in the Wisconsin Genetics Software Package, Genetics Computer Group, 575 Science Dr., Madison, WI), or by visual inspection (*see generally* Ausubel *et al.*, *supra*). One example of algorithm that is suitable for determining percent sequence identity and sequence similarity is the BLAST algorithm, which is described in Altschul *et al.*, *J. Mol. Biol.* 215:403-410 (1990). Software for performing [illegible]

[illegible] can be used [illegible] although customized parameters can also be used. [illegible] the [illegible]

BLOSUM62 scoring matrix (*see* Henikoff & Henikoff, *Proc. Natl. Acad. Sci. USA* 89, 10915 (1989))

For purposes of classifying amino acids substitutions as conservative or nonconservative, amino acids are grouped as follows: Group I (hydrophobic sidechains): norleucine, met, ala, val, leu, ile; Group II (neutral hydrophilic side chains): cys, ser, thr; Group III (acidic side chains): asp, glu; Group IV (basic side chains): asn, gln, his, lys, arg; Group V (residues influencing chain orientation): gly, pro; and Group VI (aromatic side chains): trp, tyr, phe. Conservative substitutions involve substitutions between amino acids in the same class. Non-conservative substitutions constitute exchanging a member of one of these classes for a member of another.

Therapeutic agents of the invention are typically substantially pure. This means that an agent is typically at least about 50% w/w (weight/weight) purity, as well as being substantially free from interfering proteins and contaminants. Sometimes the agents are at least about 80% w/w and, more preferably at least 90 or about 95% w/w purity. However, using conventional protein purification techniques, homogeneous peptides of at least 99% w/w can be obtained.

Specific binding between two entities means an affinity of at least 10^6, 10^7, 10^8, 10^9 M^{-1}, or 10^{10} M^{-1}. Affinities greater than 10^8 M^{-1} are preferred.

The term "antibody" is used to include intact antibodies and binding fragments thereof. Typically, fragments compete with the intact antibody from which they were derived for specific binding to an antigen. Optionally, antibodies or binding fragments thereof, can be chemically conjugated to, or [illegible]

[illegible] the human APP gene. [illegible] Ponte et al., *Nature* 331, 525 (1988); and Kitaguchi et al., [illegible] 530 [illegible]

sequence of the APP770 isoform. Terms such as Aβ39, Aβ40, Aβ41, Aβ42 and Aβ43 refer to an Aβ peptide containing amino acid residues 1-39, 1-40, 1-41, 1-42 and 1-43.

The term "epitope" or "antigenic determinant" refers to a site on an antigen to which B and/or T cells respond. B-cell epitopes can be formed both from contiguous amino acids or noncontiguous amino acids juxtaposed by tertiary folding of a protein. Epitopes formed from contiguous amino acids are typically retained on exposure to denaturing solvents whereas epitopes formed by tertiary folding are typically lost on treatment with denaturing solvents. An epitope typically includes at least 3, and more usually, at least 5 or 8-10 amino acids in a unique spatial conformation. Methods of determining spatial conformation of epitopes include, for example, x-ray crystallography and 2-dimensional nuclear magnetic resonance. See, e.g., *Epitope Mapping Protocols in Methods in Molecular Biology*, Vol. 66, Glenn E. Morris, Ed. (1996). Antibodies that recognize the same epitope can be identified in a simple immunoassay showing the ability of one antibody to block the binding of another antibody to a target antigen. T-cells recognize continuous epitopes of about nine amino acids for CD8 cells or about 13-15 amino acids for CD4 cells. T cells that recognize the epitope can be identified by *in vitro* assays that measure antigen-dependent proliferation, as determined by ^{3}H-thymidine incorporation by primed T cells in response to an epitope (Burke et al., *J. Inf. Dis.* 170, 1110-19 (1994)), by antigen-dependent killing (cytotoxic T lymphocyte assay, Tigges et al., *J. Immunol.* 156, 3901-3910) or by cytokine secretion.

The term "immunological" or "immune" response is the development of a beneficial humoral (antibody mediated) and/or [illegible] a response can be an active response induced by administration of immunogen or a passive response induced by administration of antibody or primed T-cells. A cellular immune response is elicited by the [illegible] in association with Class I or Class II MHC molecules to activate antigen-specific CD4^{+} T helper cells and/or CD8^{+} cytotoxic T cells. The response may also involve activation of monocytes, macrophages, NK

cells, basophils, dendritic cells, astrocytes, microglia cells, eosinophils or other components of innate immunity. The presence of a cell-mediated immunological response can be determined by proliferation assays ($CD4^+$ T cells) or CTL (cytotoxic T lymphocyte) assays (see Burke, supra; Tigges, supra). The relative contributions of humoral and cellular responses to the protective or therapeutic effect of an immunogen can be distinguished by separately isolating IgG and T-cells from an immunized syngeneic animal and measuring protective or therapeutic effect in a second subject.

An "immunogenic agent" or "immunogen" is capable of inducing an immunological response against itself on administration to a patient, optionally in conjunction with an adjuvant.

The term "naked polynucleotide" refers to a polynucleotide not complexed with colloidal materials. Naked polynucleotides are sometimes cloned in a plasmid vector.

The term "adjuvant" refers to a compound that when administered in conjunction with an antigen augments the immune response to the antigen, but when administered alone does not generate an immune response to the antigen. Adjuvants can augment an immune response by several mechanisms including lymphocyte recruitment, stimulation of B and/or T cells, and stimulation of macrophages.

The term "patient" includes human and other mammalian subjects that receive either prophylactic or therapeutic treatment.

Disaggregated or monomeric Aβ means soluble, monomeric [illegible] The resulting solution is centrifuged to remove any nonsoluble particulates. Aggregated Aβ is a mixture of oligomers in which the monomeric units are held together by noncovalent bonds.

Compositions or methods "comprising" one or more recited elements may include other elements not specifically recited. For example, a composition that comprises Aβ peptide

encompasses both an isolated Aβ peptide and Aβ peptide as a component of a larger polypeptide sequence.

DETAILED DESCRIPTION

I. General

The invention provides pharmaceutical compositions and methods for prophylactic and therapeutic treatment of diseases characterized by accumulation of amyloid deposits. Amyloid deposits comprise a peptide aggregated to an insoluble mass. The nature of the peptide varies in different diseases but in most cases, the aggregate has a β-pleated sheet structure and stains with Congo Red dye. Diseases characterized by amyloid deposits include Alzheimer's disease (AD), both late and early onset. In both diseases, the amyloid deposit comprises a peptide termed Aβ, which accumulates in the brain of affected individuals. Examples of some other diseases characterized by amyloid deposits are SAA amyloidosis, hereditary Icelandic syndrome, multiple myeloma, and spongiform encephalopathies, including mad cow disease, Creutzfeldt Jakob disease, sheep scrapie, and mink spongiform encephalopathy (see Weissmann et al., *Curr. Opin. Neurobiol.* 7, 695-700 (1997); Smits et al., Veterinary Quarterly 19, 101-105 (1997); Nathanson et al., Am. J. Epidemiol. 145, 959-969 (1997)). The peptides forming the aggregates in these diseases are serum amyloid A, cystantin C, IgG kappa light chain respectively for the first three, and prion protein for the others.

II. Therapeutic Agents

1. Alzheimer's Disease

Therapeutic agents for use in the present invention induce an immune response against Aβ peptide. These agents include Aβ peptide itself and variants thereof, analogs and mimetics of Aβ peptide that induce and/or crossreact with antibodies to Aβ peptide, and antibodies or T-cells reactive with Aβ peptide. Induction of an immune response can be active as when an immunogen is administered to induce antibodies or T-cells reactive with Aβ in a patient, or passive, as when an antibody is administered that itself binds to Aβ in patient.

Aβ, also known as β-amyloid peptide, or A4 peptide (see US 4,666,829; Glenner & Wong, *Biochem. Biophys. Res. Commun.* 120, 1131 (1984)), is a peptide of 39-43 amino acids, which is the principal component of characteristic plaques of Alzheimer's disease. Aβ is generated by processing of a larger protein APP by two enzymes, termed β and γ secretases (see Hardy, *TINS* 20, 154 (1997)). Known mutations in APP associated with Alzheimer's disease occur proximate to the site of β or γ secretase, or within Aβ. For example, position 717 is proximate to the site of γ-secretase cleavage of APP in its processing to Aβ, and positions 670/671 are proximate to the site of β-secretase cleavage. It is believed that the mutations cause AD disease by interacting with the cleavage reactions by which Aβ is formed so as to increase the amount of the 42/43 amino acid form of Aβ generated.

Aβ has the unusual property that it can fix and activate both classical and alternate complement cascades. In particular, it binds to Clq and ultimately to C3bi. This association facilitates binding to macrophages leading to activation of B cells. In addition, C3bi breaks down further and then binds to CR2 on B cells in a T cell dependent manner leading to a 10,000 increase in activation of these cells. This mechanism causes Aβ to generate an immune response in excess of that of other antigens.

The therapeutic agent used in the claimed methods can be any of the naturally occurring forms of Aβ peptide, and particularly the human forms (i.e., Aβ39, Aβ40, Aβ41, Aβ42 or Aβ43). The sequences of these peptides and their relationship to the APP precursor are illustrated by Fig. 3 of Hardy et al., *TINS* 20, 155-158 (1997). For example, Aβ42 has the sequence:

H_2N-Asp-Ala-Glu-Phe-Arg-His-Asp-Ser-Gly-Tyr-Glu-Val-His-His-Gln-Lys-Leu-Val-Phe-Phe-Ala-Glu-Asp-Val-Gly-Ser-Asn-Lys-Gly-Ala-Ile-Ile-Gly-Leu-Met-Val-Gly-Gly-Val-Val-IIe-Ala-OH.

Aβ41, Aβ40 and Aβ39 differ from Aβ42 by the omission of Ala, Ala-Ile, and Ala-Ile-Val respectively from the C-terminal end. Aβ43 differs from Aβ42 by the presence of a threonine residue

at the C-terminus. The therapeutic agent can also be an active fragment or analog of a natural Aβ peptide that contains an epitope that induces a similar protective or therapeutic immune response on administration to a human. Immunogenic fragments typically have a sequence of at least 3, 5, 6, 10 or 20 contiguous amino acids from a natural peptide. Immunogenic fragments include Aβ1-5, 1-6, 1-12, 13-28, 17-28, 25-25, 35-40 and 35-42. Fragments from the N-terminal half of Aβ are preferred in some methods. Analogs include allelic, species and induced variants. Analogs typically differ from naturally occurring peptides at one or a few positions, often by virtue of conservative substitutions. Analogs typically exhibit at least 80 or 90% sequence identity with natural peptides. Some analogs also include unnatural amino acids or modifications of N or C terminal amino acids. Examples of unnatural amino acids are α,α-disubstituted amino acids, N-alkyl amino acids, lactic acid, 4-hydroxyproline, γ-carboxyglutamate, ε-N,N,N-trimethyllysine, ε-N-acetyllysine, O-phosphoserine, N-acetylserine, N-formylmethionine, 3-methylhistidine, 5-hydroxylysine, ω-N-methylarginine. Fragments and analogs can be screened for prophylactic or therapeutic efficacy in transgenic animal models as described below.

Aβ, its fragments, analogs and other amyloidogenic peptides can be synthesized by solid phase peptide synthesis or recombinant expression, or can be obtained from natural sources. Automatic peptide synthesizers are commercially available from numerous suppliers, such as Applied Biosystems, Foster City, California. Recombinant expression can be in bacteria, such as E. coli, yeast, insect cells or mammalian cells. Procedures for recombinant expression are described by Sambrook et al., *Molecular Cloning: A Laboratory Manual* (C.S.H.P. Press, NY 2d ed., 1989). Some forms of Aβ peptide are also available commercially (e.g., American Peptides Company, Inc., Sunnyvale, CA and California Peptide Research, Inc. Napa, CA).

Therapeutic agents also include longer polypeptides that include, for example, an Aβ peptide, active fragment or analog

together with other amino acids. For example, Aβ peptide can be present as intact APP protein or a segment thereof, such as the C-100 fragment that begins at the N-terminus of Aβ and continues to the end of APP. Such polypeptides can be screened for prophylactic or therapeutic efficacy in animal models as described below. The Aβ peptide, analog, active fragment or other polypeptide can be administered in associated form (i.e., as an amyloid peptide) or in dissociated form. Therapeutic agents also include multimers of monomeric immunogenic agents.

In a further variation, an immunogenic peptide, such as Aβ, can be presented as a viral or bacterial vaccine. A nucleic acid encoding the immunogenic peptide is incorporated into a genome or episome of the virus or bacteria. Optionally, the nucleic acid is incorporated in such a manner that the immunogenic peptide is expressed as a secreted protein or as a fusion protein with an outersurface protein of a virus or a transmembrane protein of a bacteria so that the peptide is displayed. Viruses or bacteria used in such methods should be nonpathogenic or attenuated. Suitable viruses include adenovirus, HSV, vaccinia and fowl pox. Fusion of an immunogenic peptide to HBsAg of HBV is particularly suitable. Therapeutic agents also include peptides and other compounds that do not necessarily have a significant amino acid sequence similarity with Aβ but nevertheless serve as mimetics of Aβ and induce a similar immune response. For example, any peptides and proteins forming β-pleated sheets can be screened for suitability. Anti-idiotypic antibodies against monoclonal antibodies to Aβ or other amyloidogenic peptides can also be used. Such anti-Id antibodies mimic the antigen and generate an immune response to it (*see Essential Immunology* (Roit ed., Blackwell Scientific Publications, Palo Alto, 6th ed.), p. 181).

Random libraries of peptides or other compounds can also be screened for suitability. Combinatorial libraries can be produced for many types of compounds that can be synthesized in a step-by-step fashion. Such compounds include polypeptides, beta-turn mimetics, polysaccharides,

phospholipids, hormones, prostaglandins, steroids, aromatic compounds, heterocyclic compounds, benzodiazepines, oligomeric N-substituted glycines and oligocarbamates. Large combinatorial libraries of the compounds can be constructed by the encoded synthetic libraries (ESL) method described in Affymax, WO 95/12608, Affymax, WO 93/06121, Columbia University, WO 94/08051, Pharmacopeia, WO 95/35503 and Scripps, WO 95/30642 (each of which is incorporated by reference for all purposes). Peptide libraries can also be generated by phage display methods. *See, e.g.*, Devlin, WO 91/18980.

Combinatorial libraries and other compounds are initially screened for suitability by determining their capacity to bind to antibodies or lymphocytes (B or T) known to be specific for Aβ or other amyloidogenic peptides. For example, initial screens can be performed with any polyclonal sera or monoclonal antibody to Aβ or other amyloidogenic peptide. Compounds identified by such screens are then further analyzed for capacity to induce antibodies or reactive lymphocytes to Aβ or other amyloidogenic peptide. For example, multiple dilutions of sera can be tested on microtiter plates that have been precoated with Aβ peptide and a standard ELISA can be performed to test for reactive antibodies to Aβ. Compounds can then be tested for prophylactic and therapeutic efficacy in transgenic animals predisposed to an amyloidogenic disease, as described in the Examples. Such animals include, for example, mice bearing a 717 mutation of APP described by Games et al., supra, and mice bearing a Swedish mutation of APP such as described by McConlogue et al., US 5,612,486 and Hsiao et al., *Science* 274, 99 (1996); Staufenbiel et al., *Proc. Natl. Acad. Sci. USA* 94, 13287-13292 (1997); Sturchler-Pierrat et al., *Proc. Natl. Acad. Sci. USA* 94, 13287-13292 (1997); Borchelt et al., *Neuron* 19, 939-945 (1997)). The same screening approach can be used on other potential agents such as fragments of Aβ, analogs of Aβ and longer peptides including Aβ, described above.

Therapeutic agents of the invention also include antibodies that specifically bind to Aβ. Such antibodies can be

monoclonal or polyclonal. Some such antibodies bind specifically to the aggregated form of Aβ without binding to the dissociated form. Some bind specifically to the dissociated form without binding to the aggregated form. Some bind to both aggregated and dissociated forms. The production of non-human monoclonal antibodies, *e.g.*, murine or rat, can be accomplished by, for example, immunizing the animal with Aβ. *See* Harlow & Lane, *Antibodies, A Laboratory Manual* (CSHP NY, 1988) (incorporated by reference for all purposes). Such an immunogen can be obtained from a natural source, by peptides synthesis or by recombinant expression.

Humanized forms of mouse antibodies can be generated by linking the CDR regions of non-human antibodies to human constant regions by recombinant DNA techniques. *See* Queen et al., *Proc. Natl. Acad. Sci. USA* 86, 10029-10033 (1989) and WO 90/07861 (incorporated by reference for all purposes).

Human antibodies can be obtained using phage-display methods. *See, e.g.*, Dower et al., WO 91/17271; McCafferty et al., WO 92/01047. In these methods, libraries of phage are produced in which members display different antibodies on their outersurfaces. Antibodies are usually displayed as Fv or Fab fragments. Phage displaying antibodies with a desired specificity are selected by affinity enrichment to Aβ, or fragments thereof. Human antibodies against Aβ can also be produced from non-human transgenic mammals having transgenes encoding at least a segment of the human immunoglobulin locus and an inactivated endogenous immunoglobulin locus. *See, e.g.*, Lonberg et al., WO93/12227 (1993); Kucherlapati, WO 91/10741 (1991) (each of which is incorporated by reference in its entirety for all purposes). Human antibodies can be selected by competitive binding experiments, or otherwise, to have the same epitope specificity as a particular mouse antibody. Such antibodies are particularly likely to share the useful functional properties of the mouse antibodies. Human polyclonal antibodies can also be provided in the form of serum from humans immunized with an immunogenic agent. Optionally, such polyclonal antibodies can be concentrated by

affinity purification using Aβ or other amyloid peptide as an affinity reagent.

Human or humanized antibodies can be designed to have IgG, IgD, IgA and IgE constant region, and any isotype, including IgG1, IgG2, IgG3 and IgG4. Antibodies can be expressed as tetramers containing two light and two heavy chains, as separate heavy chains, light chains, as Fab, Fab' $F(ab')_2$, and Fv, or as single chain antibodies in which heavy and light chain variable domains are linked through a spacer.

Therapeutic agents for use in the present methods also include T-cells that bind to Aβ peptide. For example, T-cells can be activated against Aβ peptide by expressing a human MHC class I gene and a human β-2-microglobulin gene from an insect cell line, whereby an empty complex is formed on the surface of the cells and can bind to Aβ peptide. T-cells contacted with the cell line become specifically activated against the peptide. See Peterson et al., US 5,314,813. Insect cell lines expressing an MHC class II antigen can similarly be used to activate CD4 T cells.

2. Other Diseases

The same or analogous principles determine production of therapeutic agents for treatment of other amyloidogenic diseases. In general, the agents noted above for use in treatment of Alzheimer's disease can also be used for treatment early onset Alzheimer's disease associated with Down's syndrome. In mad cow disease, prion peptide, active fragments, and analogs, and antibodies to prion peptide are used in place of Aβ peptide, active fragments, analogs and antibodies to Aβ peptide in treatment of Alzheimer's disease. In treatment of multiple myeloma, IgG light chain and analogs and antibodies thereto are used, and so forth in other diseases.

3. Carrier Proteins

Some agents for inducing an immune response contain the appropriate epitope for inducing an immune response against amyloid deposits but are too small to be immunogenic. In this

situation, a peptide immunogen can be linked to a suitable carrier to help elicit an immune response. Suitable carriers include serum albumins, keyhole limpet hemocyanin, immunoglobulin molecules, thyroglobulin, ovalbumin, tetanus toxoid, or a toxoid from other pathogenic bacteria, such as diphtheria, *E. coli*, cholera, or *H. pylori*, or an attenuated toxin derivative. Other carriers for stimulating or enhancing an immune response include cytokines such as IL-1, IL-1 α and β peptides, IL-2, γINF, IL-10, GM-CSF, and chemokines, such as M1P1α and β and RANTES. Immunogenic agents can also be linked to peptides that enhance transport across tissues, as described in O'Mahony, WO 97/17613 and WO 97/17614.

Immunogenic agents can be linked to carriers by chemical crosslinking. Techniques for linking an immunogen to a carrier include the formation of disulfide linkages using N-succinimidyl-3-(2-pyridyl-thio) propionate (SPDP) and succinimidyl 4-(N-maleimidomethyl)cyclohexane-1-carboxylate (SMCC) (if the peptide lacks a sulfhydryl group, this can be provided by addition of a cysteine residue). These reagents create a disulfide linkage between themselves and peptide cysteine resides on one protein and an amide linkage through the ϵ-amino on a lysine, or other free amino group in other amino acids. A variety of such disulfide/amide-forming agents are described by *Immun. Rev.* 62, 185 (1982). Other bifunctional coupling agents form a thioether rather than a disulfide linkage. Many of these thio-ether-forming agents are commercially available and include reactive esters of 6-maleimidocaproic acid, 2-bromoacetic acid, and 2-iodoacetic acid, 4-(N-maleimido-methyl)cyclohexane-1-carboxylic acid. The carboxyl groups can be activated by combining them with succinimide or 1-hydroxyl-2-nitro-4-sulfonic acid, sodium salt.

Immunogenic peptides can also be expressed as fusion proteins with carriers. The immunogenic peptide can be linked at the amino terminus, the carboxyl terminus, or internally to the carrier. Optionally, multiple repeats of the immunogenic peptide can be present in the fusion protein.

4. Nucleic Acid Encoding Immunogens

Immune responses against amyloid deposits can also be induced by administration of nucleic acids encoding Aβ peptide or other peptide immunogens. Such nucleic acids can be DNA or RNA. A nucleic acid segment encoding the immunogen is typically linked to regulatory elements, such as a promoter and enhancer, that allow expression of the DNA segment in the intended target cells of a patient. For expression in blood cells, as is desirable for induction of an immune response, promoter and enhancer elements from light or heavy chain immunoglobulin genes or the CMV major intermediate early promoter and enhancer are suitable to direct expression. The linked regulatory elements and coding sequences are often cloned into a vector.

A number of viral vector systems are available including retroviral systems (see, e.g., Lawrie and Tumin, *Cur. Opin. Genet. Develop.* 3, 102-109 (1993)); adenoviral vectors (see, e.g., Bett et al., *J. Virol.* 67, 5911 (1993)); adeno-associated virus vectors (see, e.g., Zhou et al., *J. Exp. Med.* 179, 1867 (1994)), viral vectors from the pox family including vaccinia virus and the avian pox viruses, viral vectors from the alpha virus genus such as those derived from Sindbis and Semliki Forest Viruses (see, e.g., Dubensky et al., *J. Virol.* 70, 508-519 (1996)), and papillomaviruses (Ohe et al., *Human Gene Therapy* 6, 325-333 (1995); Woo et al., WO 94/12629 and Xiao & Brandsma, *Nucleic Acids. Res.* 24, 2630-2622 (1996)).

DNA encoding an immunogen, or a vector containing the same, can be packaged into liposomes. Suitable lipids and related analogs are described by US 5,208,036, 5,264,618, [illegible] and 5,283,185. Vectors and DNA encoding an immunogen [illegible] be adsorbed to or associated with particulate carriers, examples of which include polymethyl methacrylate polymers and polylactides and poly(lactide-co-glycolides), see, e.g., McGee et al., *J. Micro Encap.* (1996).

Gene therapy vectors or naked DNA can be delivered *in vivo* by administration to an individual patient, typically by systemic administration (e.g., intravenous, intraperitoneal, nasal, gastric, intradermal, intramuscular, subdermal, or

intracranial infusion) or topical application (see e.g., US 5,399,346). DNA can also be administered using a gene gun. See Xiao & Brandsma, *supra*. The DNA encoding an immunogen is precipitated onto the surface of microscopic metal beads. The microprojectiles are accelerated with a shock wave or expanding helium gas, and penetrate tissues to a depth of several cell layers. For example, The Accel™ Gene Delivery Device manufactured by Agacetus, Inc. Middleton WI is suitable. Alternatively, naked DNA can pass through skin into the blood stream simply by spotting the DNA onto skin with chemical or mechanical irritation (see WO 95/05853).

In a further variation, vectors encoding immunogens can be delivered to cells *ex vivo*, such as cells explanted from an individual patient (e.g., lymphocytes, bone marrow aspirates, tissue biopsy) or universal donor hematopoietic stem cells, followed by reimplantation of the cells into a patient, usually after selection for cells which have incorporated the vector.

III. Patients Amenable to Treatment

Patients amenable to treatment include individuals at risk of disease but not showing symptoms, as well as patients presently showing symptoms. In the case of Alzheimer's disease, virtually anyone is at risk of suffering from Alzheimer's disease if he or she lives long enough. Therefore, the present methods can be administered prophylactically to the general population without any assessment of the risk of the subject patient. The present methods are especially useful for individuals who do have a known genetic risk of Alzheimer's disease. [illegible] include those having relatives who have experienced this disease, and those whose risk is determined by analysis of genetic or biochemical markers. Genetic markers of risk toward Alzheimer's disease include mutations in the APP gene, particularly mutations at position 717 and positions 670 and 671 referred to as the Hardy and Swedish mutations respectively (see Hardy, *TINS*, *supra*). Other markers of risk are mutations in the presenilin genes, PS1 and PS2, and ApoE4,

family history of AD, hypercholesterolemia or atherosclerosis. Individuals presently suffering from Alzheimer's disease can be recognized from characteristic dementia, as well as the presence of risk factors described above. In addition, a number of diagnostic tests are available for identifying individuals who have AD. These include measurement of CSF tau and Aβ42 levels. Elevated tau and decreased Aβ42 levels signify the presence of AD. Individuals suffering from Alzheimer's disease can also be diagnosed by MMSE or ADRDA criteria as discussed in the Examples section.

In asymptomatic patients, treatment can begin at any age (e.g., 10, 20, 30). Usually, however, it is not necessary to begin treatment until a patient reaches 40, 50, 60 or 70. Treatment typically entails multiple dosages over a period of time. Treatment can be monitored by assaying antibody, or activated T-cell or B-cell responses to the therapeutic agent (e.g., Aβ peptide) over time. If the response falls, a booster dosage is indicated. In the case of potential Down's syndrome patients, treatment can begin antenatally by administering therapeutic agent to the mother or shortly after birth.

IV. <u>Treatment Regimes</u>

In prophylactic applications, pharmaceutical compositions or medicants are administered to a patient susceptible to, or otherwise at risk of, a particular disease in an amount sufficient to eliminate or reduce the risk or delay the outset of the disease. In therapeutic applications, compositions or medicants are administered to a patient suspected of, or already suffering from [illegible] to cure, or at least partially arrest, the symptoms of the disease and its complications. An amount adequate to accomplish this is defined as a therapeutically- or pharmaceutically-effective dose. In both prophylactic and therapeutic regimes, agents are usually administered in several dosages until a [illegible] immune response [illegible] achieved. Typically, the immune response is monitored and

repeated dosages are given if the immune response starts to fade.

Effective doses of the compositions of the present invention, for the treatment of the above described conditions vary depending upon many different factors, including means of administration, target site, physiological state of the patient, whether the patient is human or an animal, other medications administered, and whether treatment is prophylactic or therapeutic. Usually, the patient is a human, but in some diseases, such as mad cow disease, the patient can be a nonhuman mammal, such as a bovine. Treatment dosages need to be titrated to optimize safety and efficacy. The amount of immunogen depends on whether adjuvant is also administered, with higher dosages being required in the absence of adjuvant. The amount of an immunogen for administration sometimes varies from 1 μg-500 μg per patient and more usually from 5-500 μg per injection for human administration. Occasionally, a higher dose of 1-2 mg per injection is used. Typically about 10, 20, 50 or 100 μg is used for each human injection. The timing of injections can vary significantly from once a day, to once a year, to once a decade. On any given day that a dosage of immunogen is given, the dosage is greater than 1 μg/patient and usually greater than 10 μg/ patient if adjuvant is also administered, and greater than 10 μg/patient and usually greater than 100 μg/patient in the absence of adjuvant. A typical regimen consists of an immunization followed by booster injections at 6 weekly intervals. Another regimen consists of an immunization followed by [illegible] injections 1, [illegible] months [illegible] for life. Alternatively, booster injections [illegible] irregular basis as indicated by monitoring of immune response. For passive immunization with an antibody, the dosage ranges from about 0.0001 to 100 mg/kg, and more usually 0.01 to 5 mg/kg of the host body weight. Doses for nucleic acids [illegible] 100 mg, 1 μg to 10 mg, or 30-300 μg DNA per patient. Doses

for infectious viral vectors vary from $10-10^9$, or more, virions per dose.

Agents for inducing an immune response can be administered by parenteral, topical, intravenous, oral, subcutaneous, intraperitoneal, intranasal or intramuscular means for prophylactic and/or therapeutic treatment. The most typical route of administration is subcutaneous although others can be equally effective. The next most common is intramuscular injection. This type of injection is most typically performed in the arm or leg muscles. Intravenous injections as well as intraperitoneal injections, intraarterial, intracranial, or intradermal injections are also effective in generating an immune response. In some methods, agents are injected directly into a particular tissue where deposits have accumulated.

Agents of the invention can optionally be administered in combination with other agents that are at least partly effective in treatment of amyloidogenic disease. In the case of Alzheimer's and Down's syndrome, in which amyloid deposits occur in the brain, agents of the invention can also be administered in conjunction with other agents that increase passage of the agents of the invention across the blood-brain barrier.

Immunogenic agents of the invention, such as peptides, are sometimes administered in combination with an adjuvant. A variety of adjuvants can be used in combination with a peptide, such as Aβ, to elicit an immune response. Preferred adjuvants augment the intrinsic response to an immunogen without causing conform[illegible] changes [illegible] that affect the qualitative form of the response. [illegible] adjuvants include alum, [illegible] (MPL) (see GB 2220211). QS21 is a triterpene glycoside or saponin isolated from the bark of the Quillaja Saponaria Molina tree found in South America (see Kensil et al., *in Vaccine Design: The Subunit and Adjuvant Approach* (eds. Powell [illegible] Other adjuvants are oil in water emulsions (such as squalene or peanut oil), optionally in combination with immune

stimulants, such as monophosphoryl lipid A (see Stoute et al., *N. Engl. J. Med.* 336, 86-91 (1997)). Another adjuvant is CpG (*Bioworld Today*, Nov. 15, 1998). Alternatively, Aβ can be coupled to an adjuvant. For example, a lipopeptide version of Aβ can be prepared by coupling palmitic acid or other lipids directly to the N-terminus of Aβ as described for hepatitis B antigen vaccination (Livingston, *J. Immunol.* 159, 1383-1392 (1997)). However, such coupling should not substantially change the conformation of Aβ so as to affect the nature of the immune response thereto. Adjuvants can be administered as a component of a therapeutic composition with an active agent or can be administered separately, before, concurrently with, or after administration of the therapeutic agent.

A preferred class of adjuvants is aluminum salts (alum), such as aluminum hydroxide, aluminum phosphate, aluminum sulfate. Such adjuvants can be used with or without other specific immunostimulating agents such as MPL or 3-DMP, QS21, polymeric or monomeric amino acids such as polyglutamic acid or polylysine. Another class of adjuvants is oil-in-water emulsion formulations. Such adjuvants can be used with or without other specific immunostimulating agents such as muramyl peptides (e.g., N-acetylmuramyl-L-threonyl-D-isoglutamine (thr-MDP), N-acetyl-normuramyl-L-alanyl-D-isoglutamine (nor-MDP), N-acetylmuramyl-L-alanyl-D-isoglutaminyl-L-alanine-2-(1'-2'dipalmitoyl-sn-glycero-3-hydroxyphosphoryloxy)-ethylamine (MTP-PE), N-acetylglucsaminyl-N-acetylmuramyl-L-Al-D-isoglu-L-Ala-dipalmitoxy propylamide (DTP-DPP) theramide™), or other bacterial cell wall com[illegible] include (a) MF59 (WO 90/148[illegible]), containing 5% Squal[illegible], [illegible] T[illegible], and [illegible] Span [illegible] amounts of MTP-PE) formulated into submicron particles using a microfluidizer such as Model 110Y microfluidizer (Microfluidics, Newton MA), (b) SAF, containing 10% Squalane, 0.4% Tween 80, 5% pluronic-blocked polymer [illegible] and thr-MDP [illegible] generate a larger particle size emulsion, and (c) [illegible]™ adjuvant system (RAS), (Ribi Immunochem, Hamilton, MT)

containing 2% squalene, 0.2% Tween 80, and one or more bacterial cell wall components from the group consisting of monophosphorylipid A (MPL), trehalose dimycolate (TDM), and cell wall skeleton (CWS), preferably MPL + CWS (Detox™). Another class of preferred adjuvants is saponin adjuvants, such as Stimulon™ (QS21, Aquila, Worcester, MA) or particles generated therefrom such as ISCOMs (immunostimulating complexes) and ISCOMATRIX. Other adjuvants include Complete Freund's Adjuvant (CFA) and Incomplete Freund's Adjuvant (IFA). Other adjuvants include cytokines, such as interleukins (IL-1, IL-2, and IL-12), macrophage colony stimulating factor (M-CSF), tumor necrosis factor (TNF).

An adjuvant can be administered with an immunogen as a single composition, or can be administered before, concurrent with or after administration of the immunogen. Immunogen and adjuvant can be packaged and supplied in the same vial or can be packaged in separate vials and mixed before use. Immunogen and adjuvant are typically packaged with a label indicating the intended therapeutic application. If immunogen and adjuvant are packaged separately, the packaging typically includes instructions for mixing before use. The choice of an adjuvant and/or carrier depends on the stability of the vaccine containing the adjuvant, the route of administration, the dosing schedule, the efficacy of the adjuvant for the species being vaccinated, and, in humans, a pharmaceutically acceptable adjuvant is one that has been approved or is approvable for human administration by pertinent regulatory bodies. For example, Complete Freund's adjuvant is not suitable for human [illegible] preferred. Optionally, two or more different adjuvants can be [illegible] MPL, alum with QS21, MPL with QS21, and alum, QS21 [illegible] together. Also, Incomplete Freund's ajuvant can be used (Chang et al., *Advanced Drug Delivery Reviews* 32, 173-186 ([illegible])), optionally in [illegible]

Agents of the invention are often administered as pharmaceutical compositions comprising an active therapeutic

agent, *i.e.*, and a variety of other pharmaceutically acceptable components. *See Remington's Pharmaceutical Science* (15th ed., Mack Publishing Company, Easton, Pennsylvania, 1980). The preferred form depends on the intended mode of administration and therapeutic application. The compositions can also include, depending on the formulation desired, pharmaceutically-acceptable, non-toxic carriers or diluents, which are defined as vehicles commonly used to formulate pharmaceutical compositions for animal or human administration. The diluent is selected so as not to affect the biological activity of the combination. Examples of such diluents are distilled water, physiological phosphate-buffered saline, Ringer's solutions, dextrose solution, and Hank's solution. In addition, the pharmaceutical composition or formulation may also include other carriers, adjuvants, or nontoxic, nontherapeutic, nonimmunogenic stabilizers and the like. However, some reagents suitable for administration to animals, such as Complete Freund's adjuvant are not typically included in compositions for human use.

Pharmaceutical compositions can also include large, slowly metabolized macromolecules such as proteins, polysaccharides, polylactic acids, polyglycolic acids and copolymers (such as latex functionalized sepharose, agarose, cellulose, and the like), polymeric amino acids, amino acid copolymers, and lipid aggregates (such as oil droplets or liposomes). Additionally, these carriers can function as immunostimulating agents (i.e., adjuvants).

For parenteral administration, agents of the invention can be administered as injectable dosages of a solution or suspension of the substance in a physiologically acceptable [illegible] liquid such as water oil, saline, glycerol, or ethanol. Additionally, auxiliary substances, such as wetting or emulsifying agents, surfactants, pH buffering substances and the like can be present [illegible] vegetable, or synthetic origin, for example, peanut oil, soybean oil, and mineral oil. In general, glycols such as

propylene glycol or polyethylene glycol are preferred liquid carriers, particularly for injectable solutions.

Typically, compositions are prepared as injectables, either as liquid solutions or suspensions; solid forms suitable for solution in, or suspension in, liquid vehicles prior to injection can also be prepared. The preparation also can be emulsified or encapsulated in liposomes or micro particles such as polylactide, polyglycolide, or copolymer for enhanced adjuvant effect, as discussed above (see Langer, *Science* 249, 1527 (1990) and Hanes, *Advanced Drug Delivery Reviews* 28, 97-119 (1997). The agents of this invention can be administered in the form of a depot injection or implant preparation which can be formulated in such a manner as to permit a sustained or pulsatile release of the active ingredient.

Additional formulations suitable for other modes of administration include oral, intranasal, and pulmonary formulations, suppositories, and transdermal applications.

For suppositories, binders and carriers include, for example, polyalkylene glycols or triglycerides; such suppositories can be formed from mixtures containing the active ingredient in the range of 0.5% to 10%, preferably 1%-2%. Oral formulations include excipients, such as pharmaceutical grades of mannitol, lactose, starch, magnesium stearate, sodium saccharine, cellulose, and magnesium carbonate. These compositions take the form of solutions, suspensions, tablets, pills, capsules, sustained release formulations or powders and contain 10%-95% of active ingredient, preferably 25%-70%.

Topical application [illegible] intradermal delivery. [illegible] facilitated [illegible] toxin or detoxified derivatives [illegible] similar bacterial toxins (See Glenn et al., *Nature* 391, 851 (1998)). Co-administration can be achieved by using the [illegible]

Alternatively, transdermal delivery can be achieved using a skin path or using transferosomes (Paul et al., *Eur. J.*

Immunol. 25, 3521-24 (1995); Cevc et al., *Biochem. Biophys. Acta* 1368, 201-15 (1998)).

V. Methods of Diagnosis

The invention provides methods of detecting an immune response against Aβ peptide in a patient suffering from or susceptible to Alzheimer's disease. The methods are particularly useful for monitoring a course of treatment being administered to a patient. The methods can be used to monitor both therapeutic treatment on symptomatic patients and prophylactic treatment on asymptomatic patients.

Some methods entail determining a baseline value of an immune response in a patient before administering a dosage of agent, and comparing this with a value for the immune response after treatment. A significant increase (i.e., greater than the typical margin of experimental error in repeat measurements of the same sample, expressed as one standard deviation from the mean of such measurments) in value of the immune response signals a positive treatment outcome (i.e., that administration of the agent has achieved or augmented an immune response). If the value for immune response does not change significantly, or decreases, a negative treatment outcome is indicated. In general, patients undergoing an initial course of treatment with an agent are expected to show an increase in immune response with successive dosages, which eventually reaches a plateau. Administration of agent is generally continued while the immune response is increasing. Attainment of the plateau is an indicator that the administered of treatment [illegible] be discontinued [illegible] dosage or frequency.

In other methods, a control [illegible] standard deviation) of immune response is determined [illegible] control population. Typically the individuals in the control population have not received [illegible] treatment. Measured values [illegible] therapeutic agent are then compared with the control value. A significant increase relative to the control value (e.g., greater than one standard deviation from the mean) signals a

positive treatment outcome. A lack of significant increase or a decrease signals a negative treatment outcome. Administration of agent is generally continued while the immune response is increasing relative to the control value. As before, attainment of a plateau relative to control values in an indicator that the administration of treatment can be discontinued or reduced in dosage or frequency.

In other methods, a control value of immune response (e.g., a mean and standard deviation) is determined from a control population of individuals who have undergone treatment with a therapeutic agent and whose immune responses have plateaued in response to treatment. Measured values of immune response in a patient are compared with the control value. If the measured level in a patient is not significantly different (e.g., more than one standard deviation) from the control value, treatment can be discontinued. If the level in a patient is significantly below the control value, continued administration of agent is warranted. If the level in the patient persists below the control value, then a change in treatment regime, for example, use of a different adjuvant may be indicated.

In other methods, a patient who is not presently receiving treatment but has undergone a previous course of treatment is monitored for immune response to determine whether a resumption of treatment is required. The measured value of immune response in the patient can be compared with a value of immune response previously achieved in the patient after a previous course of treatment. A significant decrease relative to the previous measurement [illegible] margin of error in repeat [illegible] an indicati[illegible] value measured in [illegible] value (mean plus standard deviation) [illegible] of patients after [illegible] with a control value in populations of prophylactically treated patients who remain free of symptoms of disease, or populations of therapeutically treated patients who show

amelioration of disease characteristics. In all of these cases, a significant decrease relative to the control level (i.e., more than a standard deviation) is an indicator that treatment should be resumed in a patient.

The tissue sample for analysis is typically blood, plasma, serum, mucus or cerebral spinal fluid from the patient. The sample is analyzed for indicia of an immune response to any form of Aβ peptide, typically Aβ42. The immune response can be determined from the presence of, e.g., antibodies or T-cells that specifically bind to Aβ peptide. ELISA methods of detecting antibodies specific to Aβ are described in the Examples section. Methods of detecting reactive T-cells have been described above (see Definitions).

The invention further provides diagnostic kits for performing the diagnostic methods described above. Typically, such kits contain an agent that specifically binds to antibodies to Aβ or reacts with T-cells specific for Aβ. The kit can also include a label. For detection of antibodies to Aβ, the label is typically in the form of labelled anti-idiotypic antibodies. For detection of antibodies, the agent can be supplied prebound to a solid phase, such as to the wells of a microtiter dish. For detection of reactive T-cells, the label can be supplied as ^{3}H-thymidine to measure a proliferative response. Kits also typically contain labelling providing directions for use of the kit. The labelling may also include a chart or other correspondence regime correlating levels of measured label with levels of antibodies to Aβ or T-cells reactive with Aβ. The term labelling refers [illegible]

EXAMPLES

I. Prophylactic Efficacy of Aβ Against AD

These examples describe administration of Aβ42 peptide to transgenic mice overexpressing APP with a mutation at position 717 ($APP_{717V \rightarrow F}$) that predisposes them to develop Alzheimer's-like neuropathology. Production and characteristics of these mice (PDAPP mice) is described in Games et al., *Nature, supra*. These animals, in their heterozygote form, begin to deposit Aβ at six months of age forward. By fifteen months of age they exhibit levels of Aβ deposition equivalent to that seen in Alzheimer's disease. PDAPP mice were injected with aggregated $A\beta_{42}$ (aggregated $A\beta_{42}$) or phosphate buffered saline. Aggregated $A\beta_{42}$ was chosen because of its ability to induce antibodies to multiple epitopes of Aβ.

A. Methods

1. Source of Mice

Thirty PDAPP heterogenic female mice were randomly divided into the following groups: 10 mice to be injected with aggregated $A\beta_{42}$ (one died in transit), 5 mice to be injected with PBS/adjuvant or PBS, and 10 uninjected controls. Five mice were injected with serum amyloid protein (SAP).

2. Preparation of Immunogens

Preparation of aggregated $A\beta_{42}$: two milligrams of $A\beta_{42}$ (US Peptides Inc, lot K-42-12) was dissolved in 0.9 ml water and made up to 1 ml by adding 0.1 ml 10 x PBS. This was vortexed and allowed to incubate overnight 37° C, under which conditions the peptide aggregated. Any unused $A\beta$ was stored as a dry lyophilized powder at -20° C until the next injection.

3. Preparation of Injections

100 μg of aggregated $A\beta_{42}$ in PBS per mouse was emulsified 1:1 with Complete Freund's adjuvant (CFA) in a final volume of 400 μl emulsion for the first immunization, followed by a boost of the same amount of immunogen in Incomplete Freund's adjuvant (IFA) at 2 weeks. Two additional doses in IFA were given at monthly intervals. The subsequent immunizations were done at monthly intervals in 500 μl of PBS. Injections were delivered intraperitoneally (i.p.).

PBS injections followed the same schedule and mice were injected with a 1:1 mix of PBS/ Adjuvant at 400 μl per mouse, or 500 μl of PBS per mouse. SAP injections [illegible] the same schedule using a [illegible]

4. [illegible] and Immunohistochemistry

The above methods are described [illegible] in General Materials and Methods.

B. Results

PDAPP mice were injected with either aggregated $A\beta_{42}$ (aggregated $A\beta_{42}$), SAP peptides, or phosphate buffered saline.

A group of PDAPP mice were also left as uninjected, positive controls. The titers of the mice to aggregated $A\beta_{42}$ were monitored every other month from the fourth boost until the mice were one year of age. Mice were sacrificed at 13 months. At all time points examined, eight of the nine aggregated $A\beta_{42}$ mice developed a high antibody titer, which remained high throughout the series of injections (titers greater than 1/10000). The ninth mouse had a low, but measurable titer of approximately 1/1000 (Figure 1, Table 1). SAPP-injected mice had titers of 1:1,000 to 1:30,000 for this immunogen with only a single mice exceeding 1:10,0000.

The PBS-treated mice were titered against aggregated $A\beta_{42}$ at six, ten and twelve months. At a 1/100 dilution the PBS mice when titered against aggregated $A\beta_{42}$ only exceeded 4 times background at one data point, otherwise, they were less than 4 times background at all time points (Table 1). The SAP-specific response was negligible at these time points with all titers less than 300.

Seven out of the nine mice in the aggregated Aβ1-42 group had no detectable amyloid in their brains. In contrast, brain tissue from mice in the SAP and PBS groups contained numerous 3D6-positive amyloid deposits in the hippocampus, as well as in the frontal and cingulate cortices. The pattern of deposition was similar to that of untreated controls, with characteristic involvement of vulnerable subregions, such as the outer molecular layer of the hippocampal dentate gyrus. One mouse from the Aβ 1-42-injected group had a greatly reduced amyloid burden, confined to the hippocampus. An isolated [illegible]

Quantitative image [illegible] animals [illegible] untreated control group [illegible] than for those immunized with AN1792 (0.00%, p=0.0005). In contrast, the median value for the group immunized with SAP peptides (SAPP) was 5.74%. Brain tissue from the untreated,

control mice contained numerous Aβ amyloid deposits visualized with the Aβ-specific monoclonal antibody (mAb) 3D6 in the hippocampus, as well as in the retrosplenial cortex. A similar pattern of amyloid deposition was also seen in mice immunized with SAPP or PBS (Fig. 2). In addition, in these latter three groups there was a characteristic involvement of vulnerable subregions of the brain classically seen in AD, such as the outer molecular layer of the hippocampal dentate gyrus, in all three of these groups.

The brains that contained no Aβ deposits were also devoid of neuritic plaques that are typically visualized in PDAPP mice with the human APP antibody 8E5. All of brains from the remaining groups (SAP-injected, PBS and uninjected mice) had numerous neuritic plaques typical of untreated PDAPP mice. A small number of neuritic plaques were present in one mouse treated with AN1792, and a single cluster of dystrophic neurites was found in a second mouse treated with AN1792. Image analyses of the hippocampus, and shown in Fig. 3, demonstrated the virtual elimination of dystrophic neurites in AN1792-treated mice (median 0.00%) compared to the PBS recipients (median 0.28%, p = 0.0005).

Astrocytosis characteristic of plaque-associated inflammation was also absent in the brains of the Aβ1-42 injected group. The brains from the mice in the other groups contained abundant and clustered GFAP-positive astrocytes typical of Aβ plaque-associated gliosis. A subset of the GFAP-reacted slides were counter-stained with Thioflavin S to localize the Aβ deposits. The GFAP-positive astrocytes were [illegible]

[illegible]

significant with a median value of 1.56% for those treated with AN1792 versus median values greater than 6% for groups immunized with SAP peptides, PBS or untreated (p=0.0017)

Evidence from a subset of the Aβ 1-42- and PBS-injected mice indicated plaque-associated MHC II immunoreactivity was absent in the Aβ1-42 injected mice, consistent with lack of an Aβ-related inflammatory response.

Sections of the mouse brains were also reacted with a mAβ specific for MAC-1, a cell surface protein. MAC-1 (CD11b) is an integrin family member and exists as a heterodimer with CD18. The CD11b/CD18 complex is present on monocytes, macrophages, neutrophils and natural killer cells (Mak and Simard). The resident MAC-1-reactive cell type in the brain is likely to be microglia based on similar phenotypic morphology in MAC-1 immunoreacted sections. Plaque-associated MAC-1 labeling was lower in the brains of mice treated with AN1792 compared to the PBS control group, a finding consistent with the lack of an Aβ-induced inflammatory response.

C. Conclusion

The lack of Aβ plaques and reactive neuronal and gliotic changes in the brains of the Aβ1-42-injected mice indicate that no or extremely little amyloid was deposited in their brains, and pathological consequences, such as gliosis and neuritic pathology, were absent. PDAPP mice treated with Aβ1-42 show essentially the same lack of pathology as control nontransgenic mice. Therefore, Aβ1-42 injections are highly effective in the prevention of deposition or clearance of human Aβ from brain tissue, and elimination of subsequent neuronal and inflammatory degenerative changes. Thus, administration of Aβ peptide has therapeutic benefit in [illegible] of AD.

[illegible]

[illegible] -ve-w[illegible] s [illegible] group) were immunized with 300, [illegible]

[illegible]

intervals followed by a fourth dose one month later. The first dose was emulsified with CFA and the remaining doses were emulsified with IFA. Animals were bled 4-7 days

following each immunization starting after the second dose for measurement of antibody titers. Animals in a subset of three groups, those immunized with 11, 33, or 300 μg of antigen, were additionally bled at approximately monthly intervals for four months following the fourth immunization to monitor the decay of the antibody response across a range of vaccine doses. These animals received a final fifth immunization at seven months after study initiation. They were sacrificed one week later to measure antibody responses to AN1792 and to perform toxicological analyses.

A declining dose response was observed from 300 to 3.7 μg with no response at the two lowest doses. Mean antibody titers are about 1:1000 after 3 doses and about 1:10,000 after 4 doses of 11-300 μg of antigen (see Fig. 5).

Antibody titers rose dramatically for all but the lowest dose group following the third immunization with increases in GMTs ranging from 5- to 25-fold. Low antibody responses were then detectable for even the 0.4 μg recipients. The 1.2 and 3.7 μg groups had comparable titers with GMTs of about 1000 and the highest four doses clustered together with GMTs of about 25,000, with the exception of the 33 μg dose group with a lower GMT of 3000. Following the fourth immunization, the titer increase was more modest for most groups. There was a clear dose response across the lower antigen dose groups from 0.14 μg to 11 μg ranging from no detectable antibody for recipients of 0.14 μg to a GMT of 36,000 for recipients of 11 μg. Again, titers for the four highest dose groups of 11 to 300 μg clustered together. Thus following two immunizations, the antib[illegible]

[illegible]

blood drawn five days following the immunization (Fig. 6). This observation suggests that the peak anamnestic antibody response occurred later than 5 days post-immunization. A more

modest (50%) increase was seen at this time in the 33 μg group. In the 300 μg dose group at two months following the last dose, GMTs declined steeply by about 70%. After another month, the decline was less steep at 45% (100 μg) and about 14% for the 33 and 11 μg doses. Thus, the rate of decline in circulating antibody titers following cessation of immunization appears to be biphasic with a steep decline the first month following peak response followed by a more modest rate of decrease thereafter.

The antibody titers and the kinetics of the response of these Swiss Webster mice are similar to those of young heterozygous PDAPP transgenic mice immunized in a parallel manner. Dosages effective to induce an immune response in humans are typically similar to dosages effective in mice.

III. <u>Screen For Therapeutic Efficacy Against Established AD</u>

This assay is designed to test immunogenic agents for activity in arresting or reversing neuropathological characteristics of AD in aged animals. Immunizations with 42 amino acid long Aβ (AN1792) were begun at a timepoint when amyloid plaques are already present in the brains of the PDAPP mice.

Over the timecourse used in this study, untreated PDAPP mice develop a number of neurodegenerative changes that resemble those found in AD (Games et al., *supra* and Johnson-Wood et al., *Proc. Natl. Acad. Sci. USA* 94, 1550-1555 (1997)). The deposition of Aβ into amyloid plaques is associated with a degenerative neuronal response consisting of aberrant axonal and dendritic elements, [illegible] structure, [illegible] immunoreactive [illegible] antibodies [illegible] ultrastructural level. These characteristics allow for disease-relevant, selective and reproducible measurements of neuritic plaque formation in the PDAPP brains. The dystrophic

neuronal component of PDAPP neuritic plaques is easily visualized with an antibody specific for human APP (mAβ 8E5), and is readily measurable by computer-assisted image analysis. Therefore, in addition to measuring the effects of AN1792 on amyloid plaque formation, we monitored the effects of this treatment on the development of neuritic dystrophy.

Astrocytes and microglia are non-neuronal cells that respond to and reflect the degree of neuronal injury. GFAP-positive astrocytes and MHC II-positive microglia are commonly observed in AD, and their activation increases with the severity of the disease. Therefore, we also monitored the development of reactive astrocytosis and microgliosis in the AN1792-treated mice.

A. Materials and Methods

Forty-eight, heterozygous female PDAPP mice, 11 to 11.5 months of age, obtained from Charles River, were randomly divided into two groups: 24 mice to be immunized with 100 μg of AN1792 and 24 mice to be immunized with PBS, each combined with Freund's adjuvant. The AN1792 and PBS groups were again divided when they reached ~15 months of age. At 15 months of age approximately half of each group of the AN1792- and PBS-treated animals were euthanized (n=10 and 9, respectively), the remainder continued to receive immunizations until termination at ~18 months (n=9 and 12, respectively). A total of 8 animals (5 AN1792, 3 PBS) died during the study. In addition to the immunized animals, one-year old (n=10), 15-month old (n=10) and 18-month old (n=10) untreated PDAPP mice were incl[illegible] [illegible] compar[illegible] [illegible]

[illegible]

[illegible] lot [illegible] and [illegible] lot [illegible] [illegible] were used [illegible]

California Peptides lot [illegible] and [illegible] were used for the three additional immunizations administered between 15 and 18 months.

For immunizations, 100 μg of AN1792 in 200 μl PBS or PBS alone was emulsified 1:1 (vol:vol) with Complete Freund's adjuvant (CFA) or Incomplete Freund's adjuvant (IFA) or PBS in a final volume of 400 μl. The first immunization was delivered with CFA as adjuvant, the next four doses were given with IFA and the final four doses with PBS alone without added adjuvant. A total of nine immunizations were given over the seven-month period on a two-week schedule for the first three doses followed by a four-week interval for the remaining injections. The four-month treatment group, euthanized at 15 months of age, received only the first 6 immunizations.

B. <u>Results</u>

1. <u>Effects of AN1792 Treatment on Amyloid Burden</u>

The results of AN1792 treatment on cortical amyloid burden determined by quantitative image analysis are shown in Fig. 7. The median value of cortical amyloid burden was 0.28% in a group of untreated 12-month old PDAPP mice, a value representative of the plaque load in mice at the study's initiation. At 18 months, the amyloid burden increased over 17-fold to 4.87% in PBS-treated mice, while AN1792-treated mice had a greatly reduced amyloid burden of only 0.01%, notably less than the 12-month untreated and both the 15- and 18-month PBS-treated groups. The amyloid burden was significantly reduced in the AN1792 recipients at both 15 (96% reduction; p=0.003) and 18 (>99% reduction; p=0.0002) months.

Typically, cortical amyloid deposition in PDAPP mice initiates in the frontal and retrosplenial cortices (RSC) and [illegible]

AN1792 treatment, amyloid deposition was greatly diminished in the RSC, and the progressive involvement of the EC was

[illegible] progression of amyloid that would normally invade the temporal

and ventral cortices, as well as arrested or possibly reversed deposition in the RSC.

The profound effects of AN1792 treatment on developing cortical amyloid burden in the PDAPP mice are further demonstrated by the 18-month group, which had been treated for seven months. A near complete absence of cortical amyloid was found in the AN1792-treated mouse, with a total lack of diffuse plaques, as well as a reduction in compacted deposits.

2. AN1792 Treatment-associated Cellular and Morphological Changes

A population of Aβ-positive cells was found in brain regions that typically contain amyloid deposits. Remarkably, in several brains from AN1792 recipients, very few or no extracellular cortical amyloid plaques were found. Most of the Aβ immunoreactivity appeared to be contained within cells with large lobular or clumped soma. Phenotypically, these cells resembled activated microglia or monocytes. They were immunoreactive with antibodies recognizing ligands expressed by activated monocytes and microglia (MHC II and CD11b) and were occasionally associated with the wall or lumen of blood vessels. Comparison of near-adjacent sections labeled with Aβ and MHC II-specific antibodies revealed that similar patterns of these cells were recognized by both classes of antibodies. Detailed examination of the AN1792-treated brains revealed that the MHC II-positive cells were restricted to the vicinity of the limited amyloid remaining in these animals. Under the fixation conditions employed, the cells were not immunoreactive with [illegible]

[illegible] (CD45) [illegible]

[illegible] which [illegible]

cells were found in any of the PBS-treated mice.

PDAPP mice invariably develop heavy amyloid deposition in [illegible]

pathway, a subregion that classically contains amyloid plaques in AD. The characteristic appearance of these deposits in PBS-treated mice resembled that previously characterized in

untreated PDAPP mice. The amyloid deposition consisted of both diffuse and compacted plaques in a continuous band. In contrast, in a number of brains from AN1792-treated mice this pattern was drastically altered. The hippocampal amyloid deposition no longer contained diffuse amyloid, and the banded pattern was completely disrupted. Instead, a number of unusual punctate structures were present that are reactive with anti-Aβ antibodies, several of which appeared to be amyloid-containing cells.

MHC II-positive cells were frequently observed in the vicinity of extracellular amyloid in AN1792-treated animals. The pattern of association of Aβ-positive cells with amyloid was very similar in several brains from AN1792-treated mice. The distribution of these monocytic cells was restricted to the proximity of the deposited amyloid and was entirely absent from other brain regions devoid of Aβ plaques.

Quantitative image analysis of MHC II and MAC I-labeled sections revealed a trend towards increased immunoreactivity in the RSC and hippocampus of AN1792-treated mice compared to the PBS group which reached significance with the measure of MAC 1 reactivity in hippocampus.

These results are indicative of active, cell-mediated removal of amyloid in plaque-bearing brain regions.

3. AN1792 Effects on Aβ Levels: ELISA Determinations

(a) Cortical Levels

In untreated PDAPP mice, the median level of total Aβ in the cortex at 12 months was 1,6[illegible] ng/g, [illegible]

[illegible]

total Aβ at 15 months which increased to [illegible] ng/g at [illegible] months. In contrast, AN1792-treated animals had 81% less total Aβ at 15 months (1,600 ng/g) than the PBS-immunized [illegible]

compared (Table 2), representing a 72% reduction in the Aβ that would otherwise be present. Similar results were

obtained when cortical levels of Aβ42 were compared, namely that the AN1792-treated group contained much less Aβ42, but in this case the differences between the AN1792 and PBS groups were significant at both 15 months (p=0.04) and 18 months (p=0.0001, Table 2).

Table 2: Median Aβ Levels (ng/g) in Cortex

	UNTREATED			PBS			AN1792		
Age	**Total Aβ**	**Aβ42**	**(n)**	**Total Aβ**	**Aβ42**	**(n)**	**Total**	**Aβ42**	**(n)**
12	1,600	1,300	(10)						
15	8,700	8,300	(10)	8,600	7,200	(9)	1,600	1,300*	(10)
18	22,200	18,500	(10)	19,000	15,900	(12)	5,200**	4,000**	(9)

* p = 0.0412

** p = 0.0001

(b) <u>Hippocampal Levels</u>

In untreated PDAPP mice, median hippocampal levels of total Aβ at twelve months of age were 15,000 ng/g which increased to 51,000 ng/g at 15 months and further to 81,000 ng/g at 18 months (Table 3). Similarly, PBS immunized mice showed values of 40,000 ng/g and 65,000 ng/g at 15 months and 18 months, respectively. AN1792 immunized animals exhibited less total Aβ, specifically 25,000 ng/g and 51,000 ng/g at the respective 15-month and 18-month timepoints. The 18-month AN1792-treated group value was significantly lower than that of the PBS treated group (p= 0.0105; Table 3). Measurement of Aβ42 gave the same pattern of results [illegible]

Table 3: Median Aβ Levels (ng/g) in Hippocampus

	UNTREATED			PBS			AN1792		
Age	Total Aβ	Aβ42	(n)	Total Aβ	Aβ42	(n)	Total	Aβ42	(n)
12	15,500	11,100	(10)						
15	51,500	44,400	(10)	40,100	35,700	(9)	24,500	22,100	(10)
18	80,800	64,200	(10)	65,400	57,100	(12)	50,900*	38,900**	(9)

* p = 0.0105

** p = 0.0022

(c) <u>Cerebellar Levels</u>

In 12-month untreated PDAPP mice, the median cerebellar level of total Aβ was 15 ng/g (Table 4). At 15 months, this median increased to 28 ng/g and by 18 months had risen to 35 ng/g. PBS-treated animals displayed median total Aβ values of 21 ng/g at 15 months and 43 ng/g at 18 months. AN1792-treated animals were found to have 22 ng/g total Aβ at 15 months and significantly less (p=0.002) total Aβ at 18 months (25 ng/g) than the corresponding PBS group (Table 4).

Table 4: Median Aβ Levels (ng/g) in Cerebellum

	UNTREATED		PBS		AN1792	
Age (months)	Total Aβ	(n)	Total Aβ	(n)	Total Aβ	(n)
12	15.6	(10)				
15	27.7	(10)	20.8	(9)	21.7	(10)
18	35.0	(10)	43.1	(12)	24.8*	(9)

* p = 0.0018

4. [illegible]

[illegible]

studies to date, a slight [illegible] noted as neuropathology increases in the PDAPP mouse. In the cortex, levels of either APP-α/FL (full length) or APP-α were [illegible] unchanged [illegible] was [illegible] AN1792-treated vs. the [illegible]-treated group. The [illegible] AN1792-treated APP values were not significantly different

from values of the 12-month and 15-month untreated and 15-month PBS groups. In all cases the APP values remained within the ranges that are normally found in PDAPP mice.

5. Effects of AN1792 Treatment on Neurodegenerative and <u>Gliotic Pathology</u>

Neuritic plaque burden was significantly reduced in the frontal cortex of AN1792-treated mice compared to the PBS group at both 15 (84%; p=0.03) and 18 (55%; p=0.01) months of age (Fig. 8). The median value of the neuritic plaque burden increased from 0.32% to 0.49% in the PBS group between 15 and 18 months of age. This contrasted with the greatly reduced development of neuritic plaques in the AN1792 group, with median neuritic plaque burden values of 0.05% and 0.22%, in the 15 and 18 month groups, respectively.

Immunizations with AN1792 seemed well tolerated and reactive astrocytosis was also significantly reduced in the RSC of AN1792-treated mice when compared to the PBS group at both 15 (56%; p=0.011) and 18 (39%; p=0.028) months of age (Fig. 9). Median values of the percent of astrocytosis in the PBS group increased between 15 and 18 months from 4.26% to 5.21%. AN1792-treatment suppressed the development of astrocytosis at both time points to 1.89% and 3.2%, respectively. This suggests the neuropil was not being damaged by the clearance process.

6. <u>Antibody Responses</u>

As described above, eleven-month old heterozygous [illegible]

[illegible]

immunization with [illegible]

As a negative control, a parallel set of 24 age-matched transgenic mice received immunizations of PBS emulsified with [illegible]

immunization starting [illegible]

responses to AN1792 were measured by ELISA. Geometric mean titers (GMT) for the animals that were immunized with AN1792

were approximately 1,900, 7,600, and 45,000 following the second, third and last (sixth) doses respectively. No Aβ-specific antibody was measured in control animals following the sixth immunization.

Approximately one-half of the animals were treated for an additional three months, receiving immunizations at about 20, 24 and 27 weeks. Each of these doses was delivered in PBS vehicle alone without Freund's adjuvant. Mean antibody titers remained unchanged over this time period. In fact, antibody titers appeared to remain stable from the fourth to the eighth bleed corresponding to a period covering the fifth to the ninth injections.

To determine if the Aβ-specific antibodies elicited by immunization that were detected in the sera of AN1792-treated mice were also associated with deposited brain amyloid, a subset of sections from the AN1792- and PBS-treated mice were reacted with an antibody specific for mouse IgG. In contrast to the PBS group, Aβ plaques in AN1792-treated brains were coated with endogenous IgG. This difference between the two groups was seen in both 15-and 18-month groups. Particularly striking was the lack of labeling in the PBS group, despite the presence of a heavy amyloid burden in these mice. These results show that immunization with a synthetic Aβ protein generates antibodies that recognize and bind *in vivo* to the Aβ in amyloid plaques.

7. <u>Cellular-Mediated Immune</u> Responses

Spleens were removed [illegible] nine [illegible]

[illegible]

protein). The mitogen Con [illegible] Optimum responses were obtained with >1.7 μM protein. Cells from all nine AN1792-treated animals proliferated in response [illegible]

[illegible] was no response to the [illegible]

control animals did not respond to any of the Aβ proteins (Fig. 10, Lower Panel).

C. Conclusion

The results of this study show that AN1792 immunization of PDAPP mice possessing existing amyloid deposits slows and prevents progressive amyloid deposition and retard consequential neuropathological changes in the aged PDAPP mouse brain. Immunizations with AN1792 essentially halted amyloid developing in structures that would normally succumb to amyloidosis. Thus, administration of Aβ peptide has therapeutic benefit in the treatment of AD.

IV. Screen of Aβ Fragments

100 PDAPP mice age 9-11 months are immunized with 9 different regions of APP and Aβ to determine which epitopes convey the response. The 9 different immunogens and one control are injected i.p. as described above. The immunogens include four human Aβ peptide conjugates 1-12, 13-28, 32-42, 1-5, all coupled to sheep anti-mouse IgG via a cystine link; an APP polypeptide aa 592-695, aggregated human Aβ 1-40, and aggregated human Aβ 25-35, and aggregated rodent Aβ42. Aggregated Aβ42 and PBS are used as controls. Ten mice are used per treatment group. Titers are monitored as above and mice are euthanized at the end of 4 months of injections. Histochemistry, Aβ levels, and toxicology are determined post mortem.

[illegible]

[illegible] conjugates [illegible] each conjugated to sheep anti-mouse IgG) were prepared by coupling through an artificial cysteine added to the Aβ [illegible]

[illegible] amino acid sequences. In each case, the [illegible] inserted cysteine residue is indicated by underlining. The

Aβ13-28 peptide derivative also had two glycine residues added prior to the carboxyl terminal cysteine as indicated.

Aβ1-12 peptide	NH_2-DAEFRHDSGYEV<u>C</u> COOH
Aβ1-5 peptide	NH_2-DAEFR<u>C</u> COOH
Aβ33-42 peptide	NH_2-<u>C-amino-heptanoic acid</u>-GLMVGGVVIA COOH
Aβ13-28 peptide	Ac-NH-HHQKLVFFAEDVGSNK<u>GGC</u>-COOH

To prepare for the coupling reaction, ten mg of sheep anti-mouse IgG (Jackson ImmunoResearch Laboratories) was dialyzed overnight against 10 mM sodium borate buffer, pH 8.5. The dialyzed antibody was then concentrated to a volume of 2 mL using an Amicon Centriprep tube. Ten mg sulfo-EMCS [N (ϵ-maleimidocuproyloxy) succinimide] (Molecular Sciences Co.) was dissolved in one mL deionized water. A 40-fold molar excess of sulfo-EMCS was added dropwise with stirring to the sheep anti-mouse IgG and then the solution was stirred for an additional ten min. The activated sheep anti-mouse IgG was purified and buffer exchanged by passage over a 10 mL gel filtration column (Pierce Presto Column, obtained from Pierce Chemicals) equilibrated with 0.1 M $NaPO_4$, 5 mM EDTA, pH 6.5. Antibody containing fractions, identified by absorbance at 280 nm, were pooled and diluted to a concentration of approximately 1 mg/mL, using 1.4 mg per OD as the extinction coefficient. A 40-fold molar excess of Aβ peptide was dissolved in 20 mL of 10 mM $NaPO_4$, pH 8.0, with the exception of the Aβ33-42 peptide for which 10 mg was first dissolved in 0.5 mL of DMSO and then diluted to [illegible] mL with the [illegible] buffer. [illegible]

[illegible] final volume of less than [illegible] tube and then dialyzed against PBS to buffer exchange the buffer and remove free [illegible]. The conjugate [illegible] passed [illegible]

The concentrations of the conjugates were determined [illegible] BCA protein assay (Pierce Chemicals) with horse IgG for the

standard curve. Conjugation was documented by the molecular weight increase of the conjugated peptides relative to that of the activated sheep anti-mouse IgG. The Aβ 1-5 sheep anti-mouse conjugate was a pool of two conjugations, the rest were from a single preparation.

2. <u>Preparation of aggregated Aβ peptides</u>

Human 1-40 (AN1528; California Peptides Inc., Lot ME0541), human 1-42 (AN1792; California Peptides Inc., Lots ME0339 and ME0439), human 25-35, and rodent 1-42 (California Peptides Inc., Lot ME0218) peptides were freshly solubilized for the preparation of each set of injections from lyophilized powders that had been stored desiccated at -20°C. For this purpose, two mg of peptide were added to 0.9 ml of deionized water and the mixture was vortexed to generate a relatively uniform solution or suspension. Of the four, AN1528 was the only peptide soluble at this step. A 100 μl aliquot of 10X PBS (1X PBS: 0.15 M NaCl, 0.01 M sodium phosphate, pH 7.5) was then added at which point AN1528 began to precipitate. The suspension was vortexed again and incubated overnight at 37°C for use the next day.

Preparation of the pBx6 protein: An expression plasmid encoding pBx6, a fusion protein consisting of the 100-amino acid bacteriophage MS-2 polymerase N-terminal leader sequence followed by amino acids 592-695 of APP (βAPP) was constructed as described by Oltersdorf et al., *J. Biol. Chem.* 265, 4492-4497 (1990). The plasmid was [illegible] protein [illegible] The [illegible]

[illegible] by Western blo[illegible] antibody, pooled, concentrated using an Amicon Centriprep tube and dialysed against PBS. The [illegible] of the preparation

B. Results and Discussion

1. Study Design

One hundred male and female, nine- to eleven-month old heterozygous PDAPP transgenic mice were obtained from Charles River Laboratory and Taconic Laboratory. The mice were sorted into ten groups to be immunized with different regions of Aβ or APP combined with Freund's adjuvant. Animals were distributed to match the gender, age, parentage and source of the animals within the groups as closely as possible. The immunogens included four Aβ peptides derived from the human sequence, 1-5, 1-12, 13-28, and 33-42, each conjugated to sheep anti-mouse IgG; four aggregated Aβ peptides, human 1-40 (AN1528), human 1-42 (AN1792), human 25-35, and rodent 1-42; and a fusion polypeptide, designated as pBx6, containing APP amino acid residues 592-695. A tenth group was immunized with PBS combined with adjuvant as a control.

For each immunization, 100 μg of each Aβ peptide in 200 μl PBS or 200 μg of the APP derivative pBx6 in the same volume of PBS or PBS alone was emulsified 1:1 (vol:vol) with Complete Freund's adjuvant (CFA) in a final volume of 400 μl for the first immunization, followed by a boost of the same amount of immunogen in Incomplete Freund's adjuvant (IFA) for the subsequent four doses and with PBS for the final dose. Immunizations were delivered intraperitoneally on a biweekly schedule for the first three doses, then on a monthly schedule thereafter. Animals were bled four to seven days following each immunization starting after the second dose for the [illegible] of antibody [illegible] [illegible] week af[illegible]

Following about four mo[illegible] [illegible]zation with the various Aβ peptides or the APP derivative, brains were removed from saline-perfused [illegible]. One hemisphere [illegible] prepared for

[illegible]

amyloid precursor protein, the hemisphere was [illegible] and

homogenates of the hippocampal, cortical, and cerebellar regions were prepared in 5 M guanidine. These were diluted and the level of amyloid or APP was quantitated by comparison to a series of dilutions of standards of Aβ peptide or APP of known concentrations in an ELISA format.

The median concentration of total Aβ for the control group immunized with PBS was 5.8-fold higher in the hippocampus than in the cortex (median of 24,318 ng/g hippocampal tissue compared to 4,221 ng/g for the cortex). The median level in the cerebellum of the control group (23.4 ng/g tissue) was about 1,000-fold lower than in the hippocampus. These levels are similar to those that we have previously reported for heterozygous PDAPP transgenic mice of this age (Johnson-Woods et al., 1997, supra).

For the cortex, a subset of treatment groups had median total Aβ and Aβ1-42 levels which differed significantly from those of the control group ($p < 0.05$), those animals receiving AN1792, rodent Aβ1-42 or the Aβ1-5 peptide conjugate as shown in **Fig. 11**. The median levels of total Aβ were reduced by 75%, 79% and 61%, respectively, compared to the control for these treatment groups. There were no discernable correlations between Aβ-specific antibody titers and Aβ levels in the cortical region of the brain for any of the groups.

In the hippocampus, the median reduction of total Aβ associated with AN1792 treatment (46%, $p = 0.0543$) was not as great as that observed in the cortex (75%, $p = 0.0021$). However, the magnitude of the reduction was far greater in the hippocampus than in the [illegible] in the hippocampus [illegible] For group of ani[illegible] Aβ1-5, the median total Aβ levels were reduced by 36% and 26%, respectively. However, given the small group sizes and the high variability of the amyloid peptide levels from animal to animal within both groups, these reductions were not significant. When the levels of Aβ1-42 were measured in the [illegible]

[illegible]

cortex, changes in this region are a more sensitive indicator

of treatment effects. The changes in Aβ levels measured by ELISA in the cortex are similar, but not identical, to the results from the immunohistochemical analysis (see below).

Total Aβ was also measured in the cerebellum, a region typically unaffected in the AD pathology. None of the median Aβ concentrations of any of the groups immunized with the various Aβ peptides or the APP derivative differed from that of the control group in this region of the brain. This result suggests that non-pathological levels of Aβ are unaffected by treatment.

APP concentration was also determined by ELISA in the cortex and cerebellum from treated and control mice. Two different APP assays were utilized. The first, designated APP-α/FL, recognizes both APP-alpha (α, the secreted form of APP which has been cleaved within the Aβ sequence), and full-length forms (FL) of APP, while the second recognizes only APP-α. In contrast to the treatment-associated diminution of Aβ in a subset of treatment groups, the levels of APP were unchanged in all of the treated compared to the control animals. These results indicate that the immunizations with Aβ peptides are not depleting APP; rather the treatment effect is specific to Aβ.

In summary, total Aβ and Aβ1-42 levels were significantly reduced in the cortex by treatment with AN1792, rodent Aβ1-42 or Aβ1-5 conjugate. In the hippocampus, total Aβ was significantly reduced only by AN1792 treatment. No other treatment-associated changes [illegible] APP [illegible] hippocampal, cortical [illegible]

2. Histochemical [illegible]

Brains from a subset of six groups were prepared for immunohistochemical analysis, three groups immunized with the Aβ peptide conjugates Aβ1-5, Aβ1-12, and Aβ13-28; two groups immunized with the full length Aβ aggregates AN1792 and AN1528 and the PBS-treated control group. The results of image [illegible]

[illegible]

reductions of amyloid burden in the cortical regions of three

of the treatment groups versus control animals. The greatest reduction of amyloid burden was observed in the group receiving AN1792 where the mean value was reduced by 97% ($p = 0.001$). Significant reductions were also observed for those animals treated with AN1528 (95%, $p = 0.005$) and the Aβ1-5 peptide conjugate (67%, $p = 0.02$).

The results obtained by quantitation of total Aβ or Aβ1-42 by ELISA and amyloid burden by image analysis differ to some extent. Treatment with AN1528 had a significant impact on the level of cortical amyloid burden when measured by quantitative image analysis but not on the concentration of total Aβ in the same region when measured by ELISA. The difference between these two results is likely to be due to the specificities of the assays. Image analysis measures only insoluble Aβ aggregated into plaques. In contrast, the ELISA measures all forms of Aβ, both soluble and insoluble, monomeric and aggregated. Since the disease pathology is thought to be associated with the insoluble plaque-associated form of Aβ, the image analysis technique may have more sensitivity to reveal treatment effects. However since the ELISA is a more rapid and easier assay, it is very useful for screening purposes. Moreover it may reveal that the treatment-associated reduction of Aβ is greater for plaque-associated than total Aβ.

To determine if the Aβ-specific antibodies elicited by immunization in the treated animals reacted with deposited [illegible] containing plaques were coated with endogenous IgG for animals immunized with the Aβ peptide conjugates Aβ1-5, Aβ1-12, and Aβ13-28; and the full length Aβ aggregates AN1792 and AN1528. Brains from animals immunized with the other Aβ peptides or the APP peptide pBx6 were not analyzed by this assay.

[illegible]

[illegible] immunization starting after the second immunization, for a

total of five bleeds. Antibody titers were measured as Aβ1-42-binding antibody using a sandwich ELISA with plastic multi-well plates coated with Aβ1-42. As shown in Fig. 13, peak antibody titers were elicited following the fourth dose for those four vaccines which elicited the highest titers of AN1792-specific antibodies: AN1792 (peak GMT: 94,647), AN1528 (peak GMT: 88,231), Aβ1-12 conjugate (peak GMT: 47,216)and rodent Aβ1-42 (peak GMT: 10,766). Titers for these groups declined somewhat following the fifth and sixth doses. For the remaining five immunogens, peak titers were reached following the fifth or the sixth dose and these were of much lower magnitude than those of the four highest titer groups: Aβ1-5 conjugate (peak GMT: 2,356), pBx6 (peak GMT: 1,986), Aβ13-28 conjugate (peak GMT: 1,183), Aβ33-42 conjugate (peak GMT: 658), Aβ25-35 (peak GMT: 125). Antibody titers were also measured against the homologous peptides using the same ELISA sandwich format for a subset of the immunogens, those groups immunized with Aβ1-5, Aβ13-28, Aβ25-35, Aβ33-42 or rodent Aβ1-42. These titers were about the same as those measured against Aβ1-42 except for the rodent Aβ1-42 immunogen in which case antibody titers against the homologous immunogen were about two-fold higher. The magnitude of the AN1792-specific antibody titer of individual animals or the mean values of treatment groups did not correlate with efficacy measured as the reduction of Aβ in the cortex.

[illegible]

[illegible] sixth immunization. Freshly harvested cells, [illegible] per well, were cultured for 5 days in the presence of Aβ1-40 at a concentration of 5 μM for stimulation. Cells from a subset of seven of the ten groups were also cultured in the presence of the reverse peptide, Aβ40-1. As a positive control, additional cells were cultured with the T cell mitogen, PHA, and, as a negative control, cells were cultured [illegible]

Lymphocytes from a majority of the animals proliferated in response to PHA. There were no significant responses to the Aβ40-1 reverse peptide. Cells from animals immunized with the larger aggregated Aβ peptides, AN1792, rodent Aβ1-42 and AN1528 proliferated robustly when stimulated with Aβ1-40 with the highest cpm in the recipients of AN1792. One animal in each of the groups immunized with Aβ1-12 conjugate, Aβ13-28 conjugate and Aβ25-35 proliferated in response to Aβ1-40. The remaining groups receiving Aβ1-5 conjugate, Aβ33-42 conjugate pBx6 or PBS had no animals with an Aβ-stimulated response. These results are summarized in Table 5 below.

Table 5			
Immunogen	Conjugate	Aβ Amino Acids	Responders
Aβ1-5	yes	5-mer	0/7
Aβ1-12	yes	12-mer	1/9
Aβ13-28	yes	16-mer	1/9
Aβ25-35		11-mer	1/9
Aβ33-42	yes	10-mer	0/10
Aβ1-40		40-mer	5/8
Aβ1-42		42-mer	9/9
r Aβ1-42		42-mer	8/8
pBx6			0/8
PBS		0-mer	0/8

These results show that [illegible] stimulate [illegible] with Aβ1-5 is not surprising since peptide [illegible] by $CD4^+$ T cells are usually about 15 amino acids in length, although shorter peptides can sometimes function with less efficiency. Thus the majority of helper T cell epitopes for the four conjugate peptides are likely to reside in the IgG conjugate partner, not in the Aβ region. This hypothesis is supported by the very low [illegible] for animals in each of [illegible] 5 conjugate was effective at significantly reducing the level

of Aβ in the brain, in the apparent absence of Aβ-specific T cells, the key effector immune response induced by immunization with this peptide appears to be antibody.

Lack of T-cell and low antibody response from fusion peptide pBx6, encompassing APP amino acids 592-695 including all of the Aβ residues may be due to the poor immunogenicity of this particular preparation. The poor immunogenicity of the Aβ25-35 aggregate is likely due to the peptide being too small to be likely to contain a good T cell epitope to help the induction of an antibody response. If this peptide were conjugated to a carrier protein, it would probably be more immunogenic.

V. Preparation of Polyclonal Antibodies for Passive Protection

20 non-transgenic mice are immunized with Aβ or other immunogen, optionally plus adjuvant, and are euthanized at 4-5 months. Blood is collected from immunized mice. Optionally, IgG is separated from other blood components. Antibody specific for the immunogen may be partially purified by affinity chromatography. An average of about 0.5-1 mg of immunogen-specific antibody is obtained per mouse, giving a total of 5-10 mg.

VI. Passive Immunization with [illegible]

Groups of 7-9 month old PDAPP mice each are injected with 0.5 mg in PBS of polyclonal anti-Aβ or specific anti-Aβ monoclonals as shown below. All antibody preparations are purified to have low endotoxin levels. [illegible] longer form of Aβ into a mouse, preparing hybridomas and screening the hybridomas for an antibody that specifically

binds to a desired fragment of Aβ without binding to other nonoverlapping fragments of Aβ.

Table 6

Antibody	Epitope
2H3	Aβ 1-12
10D5	Aβ 1-12
266	Aβ 13-28
21F12	Aβ 33-42
Mouse polyclonal anti-human Aβ42	Anti-Aggregated Aβ42

Mice are injected ip as needed over a 4 month period to maintain a circulating antibody concentration measured by ELISA titer of greater than 1/1000 defined by ELISA to Aβ42 or other immunogen. Titers are monitored as above and mice are euthanized at the end of 4 months of injections. Histochemistry, Aβ levels and toxicology are performed post mortem. Ten mice are used per group.

VII. Comparison of Different [illegible]

This examples compares CFA, alum, an oil-in water emulsion and MPL for capacity to stimulate an immune response.

A. Materials and Methods

1. Study Design

One hundred female Hartley strain six-week old guinea pigs, obtained from Elm Hill, were sorted into ten groups to be immunized with AN1792 or a palmitoylated derivative thereof combined with various adjuvants. Seven groups received injections of AN1792 (33μg unless otherwise specified) combined with a) PBS, b) Freund's adjuvant, c) MPL, d) squalene, e) MPL/squalene f) low dose alum, or g) high dose alum (300μg AN1792). Two groups received injections of a palmitoylated derivative of AN1792 (33 μg) combined with a) PBS or b) squalene. A final, tenth group received PBS alone without antigen or additional adjuvant. For the group receiving Freund's adjuvant, the first dose was emulsified with CFA and the remaining four doses with IFA. Antigen was administered at a dose of 33 μg for all groups except the high dose alum group, which received 300 μg of AN1792. Injections were administered intraperitoneally for CFA/IFA and intramuscularly in the hind limb quadriceps alternately on the right and left side for all other groups. The first three doses were given on a biweekly schedule followed by two doses at a monthly interval). Blood was drawn six to seven days following each immunization, starting after the second dose, for measurement of antibody titers.

2. [illegible]

Two mg Aβ42 (California Peptide, Lot ME0339) was added to 0.9 ml of deionized water and the mixture was vortexed to generate a relatively uniform suspension. A 100 μl aliquot of 10X PBS (1X PBS, 0.15 M NaCl, 0.01 M sodium phosphate, pH 7.5) [illegible] overnight at 37°C [illegible] stored with desiccant as a lyophilized powder at -20°C.

A palmitoylated derivative of AN1792 was prepared by coupling palmitic anhydride, dissolved in dimethyl formamide, to the amino terminal residue of AN1792 prior to removal of the nascent peptide from the resin by treatment with hydrofluoric acid.

To prepare vaccine doses with Complete Freund's adjuvant (CFA) (group 2), 33 μg of AN1792 in 200 μl PBS was emulsified 1:1 (vol:vol) with CFA in a final volume of 400 μl for the first immunization. For subsequent immunizations, the antigen was similarly emulsified with Incomplete Freund's adjuvant (IFA).

To prepare vaccine doses with MPL for groups 5 and 8, lyophilized powder (Ribi ImmunoChem Research, Inc., Hamilton, MT) was added to 0.2% aqueous triethylamine to a final concentration of 1 mg/ml and vortexed. The mixture was heated to 65 to 70°C for 30 sec to create a slightly opaque uniform suspension of micelles. The solution was freshly prepared for each set of injections. For each injection in group 5, 33 μg of AN1792 in 16.5 μl PBS, 50 μg of MPL (50 μl) and 162 μl of PBS were mixed in a borosilicate tube immediately before use.

To prepare vaccine doses with the low oil-in-water emulsion, AN1792 in PBS was added to 5% squalene, 0.5% Tween 80, 0.5% Span 85 in PBS to reach a final single dose concentration of 33 μg AN1792 in 250 μl (group 6). The mixture was emulsified by passing through a two [illegible] device 15 to 20 times until [illegible] be about equal in diameter [illegible] bead when viewed under a microscope. The resulting suspension was opalescent, milky white. The emulsions were freshly prepared for each series of injections. For group 8, MPL in 0.2% triethylamine was added at a concentration of 50 μg per dose to the squalene and detergent mixture for emulsification [illegible]

[illegible] vortexed. Tween 80 and Span 85 were then added with

vortexing. This mixture was added to PBS to reach final concentrations of 5% squalene, 0.5% Tween 80, 0.5% Span 85 and the mixture was emulsified as noted above.

To prepare vaccine doses with alum (groups 9 and 10), AN1792 in PBS was added to Alhydrogel (aluminum hydroxide gel, Accurate, Westbury, NY) to reach concentrations of 33 μg (low dose, group 9) or 300 μg (high dose, group 10) AN1792 per 5 mg of alum in a final dose volume of 250 μl. The suspension was gently mixed for 4 hr at RT.

3. Measurement of Antibody Titers

Guinea pigs were bled six to seven days following immunization starting after the second immunization for a total of four bleeds. Antibody titers against Aβ42 were measured by ELISA as described in General Materials and Methods.

4. Tissue Preparation

After about 14 weeks, all guinea pigs were administered CO_2. Cerebrospinal fluid was collected and the brains were [illegible]

B. Results

1. Antibody Responses

There was a wide range in the potency of the various adjuvants when measured as the antibody response to AN1792 following immunization. As shown in **Fig. 14**, when AN1792 was administered in PBS, no antibody was detected following two or three immunizations and negligible responses were detected following the fourth and fifth doses with geometric mean titers (GMTs) of only about 45. The o/w emulsion induced modest titers following the third dose (GMT 255) that were maintained following the fourth dose (GMT 301) and fell with the final dose (GMT 54). There was a clear antigen dose response for AN1792 bound to alum with 300 μg being more immunogenic at all time points than 33 μg. At the peak of the antibody response, following the fourth immunization, the difference between the two doses was 43% with GMTs of about 1940 (33 μg) and 3400 (300 μg). The antibody response to 33 μg AN1792 plus MPL was very similar to that generated with almost a ten-fold higher dose of antigen (300 μg) bound to alum. The addition of MPL to an o/w emulsion decreased the potency of the vaccine relative to that with MPL as the sole adjuvant by as much as 75%. A palmitoylated derivative of AN1792 was completely non-immunogenic when administered in PBS and gave modest titers when presented in an o/w emulsion with GMTs of 340 and [illegible] for the third and fourth bleeds. [illegible] MPL and high dose AN1792/alum.

The most promising adjuvants identified in this study are MPL and alum. Of these two, MPL appears preferable because a 10-fold lower antigen dose was required to generate the same [illegible] and by optimizing the immunization schedule. The o/w emulsion [illegible]

was a very weak adjuvant for AN1792 and adding an o/w emulsion to MPL adjuvant diminished the [illegible] of MPL alone.

2.. $A\beta$ Levels In The Brain

At about 14 weeks the guinea pigs were deeply anesthetized, the cerebrospinal fluid (CSF) was drawn and brains were excised from animals in a subset of the groups, those immunized with Freund's adjuvant (group 2), MPL (group 5), alum with a high dose, 300 μg, of AN1792 (group 10) and the PBS immunized control group (group 3). To measure the level of $A\beta$ peptide, one hemisphere was dissected and homogenates of the hippocampal, cortical, and cerebellar regions were prepared in 5 M guanidine. These were diluted and quantitated by comparison to a series of dilutions of $A\beta$ standard protein of known concentrations in an ELISA format. The levels of $A\beta$ protein in the hippocampus, the cortex and the cerebellum were very similar for all four groups despite the wide range of antibody responses to $A\beta$ elicited by these vaccines. Mean $A\beta$ levels of about 25 ng/g tissue were measured in the hippocampus, 21 ng/g in the cortex, and 12 ng/g in the cerebellum. Thus, the presence of a high circulating antibody titer to $A\beta$ for almost three months in some of these animals did not [illegible]

[illegible]

response is focused on [illegible]

[illegible]

study with 10-13 [illegible] per group. [illegible]

on days 0, 14, 28, 60, 90 and 20 administered subcutaneously in a dose volume of 200 µl. PBS was used as the buffer for all formulations. Animals were bleed seven days following each immunization starting after the second dose for analysis of antibody titers by ELISA. The treatment regime of each group is summarized in Table 7.

Table 7

Experimental Design of Betabloc Study 010					
Group	N [a]	Adjuvant [b]	Dose	Antigen	Dose (μg)
1	10	MPL	12.5 μg	AN1792	33
2	10	MPL	25 μg	AN1792	33
3	10	MPL	50 μg	AN1792	33
4	13	MPL	125 μg	AN1792	33
5	13	MPL	50 μg	AN1792	150
6	13	MPL	50 μg	AN1528	33
7	10	PBS		AN1792	33
8	10	PBS		none	
9	10	Squalene emulsified	5%	AN1792	33
10	10	Squalene admixed	5%	AN1792	33
11	10	Alum	2 mg	AN1792	33
12	13	MPL + Alum	50 μg/2 mg	AN1792	33
13	10	QS21	5 μg	AN1792	33
14	10	QS21	10 μg	AN1792	33
15	10	QS21	25 μg	AN1792	33
16	13	QS21	25 μg	AN1792	150
17	13	QS21	25 μg	AN1528	33
18	13	QS21 + [illegible]	2[illegible]/50 μg	A[illegible]	[illegible]
[illegible]	1[illegible]	QS21 + A[illegible]	[illegible]	A[illegible]	[illegible]

Footnotes

[a] Number of mice in each group at the initiation of the experiment.

[b] The adjuvants are noted. The buffer for all these formulations was PBS. For group 8, there was no adjuvant and no antigen.

[illegible]

Table 8.

Geometric Mean Antibody Titers					
Week of Bleed					
Treatment Group	2.9	5.0	8.7	12.9	16.7
1	248	1797	2577	6180	4177
2	598	3114	3984	5287	6878
3	1372	5000	7159	12333	12781
4	1278	20791	14368	20097	25631
5	3288	26242	13229	9315	23742
6	61	2536	2301	1442	4504
7	37	395	484	972	2149
8	25	25	25	25	25
9	25	183	744	952	1823
10	25	89	311	513	817
11	29	708	2618	2165	3666
12	198	1458	1079	612	797
13	38	433	566	1080	626
14	104	541	3247	1609	838
15	212	2630	2472	1224	1496
16	183	2616	6680	2085	1631
17	28	201	375	222	1540
18	31699	15544	23095	6412	9059
19	63	243	554	299	441

T[illegible] the adjuvants were 125 μg MPL, [illegible]

IX. Therapeutic Efficacy of Different Adjuvants

A therapeutic efficacy study was [illegible] in PDAPP transgenic mice with a set of [illegible] responses to Aβ and to [illegible] amyloid deposits in the brain.

One hundred eighty male and female, 7.5- to 8.5-month old heterozygous PDAPP transgenic mice were obtained from Charles River Laboratories. The mice were sorted into [illegible] containing 15 to 23 animals per group to be immunized with AN1792 or AN1528 combined with various adjuvants. Animals were distributed to match the gender, age, and parentage of the animals within the groups as closely as possible. The adjuvants included alum, MPL, and QS21, each combined with both antigens, and Freund's adjuvant (FA) combined with only AN1792. An additional group was immunized with AN1792 formulated in PBS buffer plus the preservative thimerosal without adjuvant. A ninth group was immunized with PBS alone as a negative control.

Preparation of aggregated Aβ peptides: human Aβ1-40 (AN1528; California Peptides Inc., Napa, CA; Lot ME0541) and human Aβ1-42 (AN1792; California Peptides Inc., Lot ME0439) peptides were freshly solubilized for the preparation of each set of injections from lyophilized powders that had been stored desiccated at -20°C. For this purpose, two mg of peptide were added to 0.9 ml of deionized water and the mixture was vortexed to generate a relatively uniform solution or suspension. AN1528 was soluble at this step, in contrast to AN1792. A 100 μl aliquot of 10X PBS (1X PBS: 0.15 M NaCl, 0.01 M sodium phosphate, pH 7.5) was then added at which point AN1528 began to precipitate. The suspensions were vortexed again and incubated over [illegible]

[illegible] peptide in PBS was added to Alhydrogel (two [illegible] aluminum hydroxide gel, Sargeant, Inc., Clifton, NJ) to reach concentrations of 100 μg Aβ peptide per 1 mg of alum. [illegible] was added to a final dose volume of 200 μl in 1X PBS. The suspension was then gently mixed for approximately 4 hr at RT prior to injection.

[illegible] lyophilized powder (Ribi ImmunoChem Research, Inc., Hamilton,

MT; Lot 67039-E0896B) was added to 0.2% aqueous triethylamine to a final concentration of 1 mg/ml and vortexed. The mixture was heated to 65 to 70°C for [illegible] to create a [illegible] opaque uniform suspension of micelles. The solution was stored at 4°C. For each set of injections, 100 μg of peptide per dose in 50 μl PBS, 50 μg of MPL per dose (50 μl) and 100 μl of PBS per dose were mixed in a borosilicate tube immediately before use.

To prepare vaccine doses with QS21 (Groups 3 and 7), lyophilized powder (Aquila, Framingham, MA; Lot A7018R) was added to PBS, pH 6.6-6.7 to a final concentration of 1 mg/ml and vortexed. The solution was stored at -20°C. For each set of injections, 100 μg of peptide per dose in 50 μl PBS, 25 μg of QS21 per dose in 25 μl PBS and 125 μl of PBS per dose were mixed in a borosilicate tube immediately before use.

To prepare vaccine doses with Freund's Adjuvant (Group 4), 100 μg of AN1792 in 200 μl PBS was emulsified 1:1 (vol:vol) with Complete Freund's Adjuvant (CFA) in a final volume of 400 μl for the first immunization. For subsequent immunizations, the antigen was similarly emulsified with Incomplete Freund's Adjuvant (IFA). For the vaccines containing the adjuvants alum, MPL or QS21, 100 μg per dose of AN1792 or AN1528 was combined with alum (1 mg per dose) or MPL (50 μg per dose) or QS21 (25 μg per dose) in a final volume of 200 μl PBS and [illegible]

[illegible]

[illegible] emulsified [illegible] complete [illegible] (CFA) in a final volume of [illegible] μl and delivered intraperitoneally for the f[illegible], f[illegible] boost of the same amount [illegible] adjuvant (IFA) for the subsequent five doses. F[illegible] receiving AN1792 without [illegible] μg AN1792 [illegible] [illegible] final volume [illegible] and [illegible] The ninth [illegible] received [illegible] cutaneous[illegible] [illegible]ons we[illegible] given on a biweekly schedule for the first three doses, then

on a monthly schedule thereafter on days 0, 16, 28, 56, 85 and 1[illegible]. Animals were bled six to seven days following each immunization [illegible] the [illegible] measurement of antibody titers. Animals were euthanized approximately one week after the final dose. Outcomes were measured by ELISA assay of Aβ and APP levels in brain and by immunohistochemical evaluation of the presence of amyloid plaques in brain sections. In addition, Aβ-specific antibody titers, and Aβ-dependent proliferative and cytokine responses were determined.

Table 9 shows that the highest antibody titers to Aβ1-42 were elicited with FA and AN1792, titers which peaked following the fourth immunization (peak GMT: 75,386) and then declined by 59% after the final, sixth immunization. The peak mean titer elicited by MPL with AN1792 was 62% lower than that generated with FA (peak GMT: 28,867) and was also reached early in the immunization scheme, after 3 doses, followed by a decline to 28% of the peak value after the sixth immunization. The peak mean titer generated with QS21 combined with AN1792 (GMT: 1,511) was about 5-fold lower than obtained with MPL. In addition, the kinetics of the response were slower, since an additional immunization was required to reach the peak response. Titers generated by alum-bound AN1792 were marginally greater than those obtained with QS21 and the response kinetics were more rapid. For AN1792 delivered in [illegible]

[illegible]

fold lower than those with [illegible]

[illegible]

control anim[illegible]

Table 9

Geometric Mean Antibody Titers[a]					
	Week of Bleed				
Treatment	3.3	5.0	9.0	13.0	17.0
Alum/ AN1792	102 (12/21)[b]	1,081 (17/20)	2,366 (21/21)	1,083 (19/21)	572 (18/21)
MPL/ AN1792	6241 (21/21)	28,867 (21/21)	1,1242 (21/21)	5,665 (20/20)	8,204 (20/20)
QS21/ AN1792	30 (1/20)	227 (10/19)	327 (10/19)	1,511 (17/18)	1,188 (14/18)
CFA/ AN1792	10,076 (15/15)	61,279 (15/15)	75,386 (15/15)	41,628 (15/15)	30,574 (15/15)
Alum/ AN1528	25 (0/21)	33 (1/21)	39 (3/20)	37 (1/20)	31 (2/20)
MPL/ AN1528	184 (15/21)	2,591 (20/21)	1,653 (21/21)	1,156 (20/20)	3,099 (20/20)
QS21/ AN1528	29 (1/22)	221 (13/22)	51 (4/22)	820 (20/22)	2,994 (21/22)
PBS plus	25	33	39	37	47

[a] Geom[illegible] titers measure[illegible]

[b] Number of responders per group

The results of AN1792 or [illegible] treatment with [illegible] adjuvants, or thimerosal on cortical amyloid burden [illegible] month old mice determined by ELISA are shown in Fig. 1[illegible]. In PBS control PDAPP mice, the median level of total $A\beta$ in the

cortex at 12 months was 1,817 ng/g. Notably reduced levels of Aβ were observed in mice treated with AN1792 plus CFA/IFA, AN1792 plus alum, AN1792 [illegible] reduction reached statistical significance (p<0.05) only for AN1792 plus CFA/IFA. However, as shown in Examples I and III, the effects of immunization in reducing Aβ levels become substantially greater in 15 month and 18 month old mice. Thus, it is expected that at least the AN1792 plus alum, AN1792 plus MPL and AN1792 plus QS21 compositions will achieve statistical significance in treatment of older mice. By contrast, the AN1792 plus the preservative thimerosal showed a median level of Aβ about the same as that in the PBS treated mice. Similar results were obtained when cortical levels of Aβ42 were compared. The median level of Aβ42 in PBS controls was 1624 ng/g. Notably reduced median levels of 403, 1149, 620 and 714 were observed in the mice treated with AN1792 plus CFA/IFA, AN1792 plus alum, AN1792 plus MPL and AN1792 plus QS21 respectively, with the reduction achieving statistical significance (p=0.05) for the AN1792 CFA/IFA treatment group. The median level in the AN1792 thimerosal treated mice was 1619 ng/g Aβ42.

X. Toxicity Analysis

[illegible]

on terminal blood [illegible] major organs were [illegible] lymphoid, gastro[illegible] [illegible]r, k[illegible] Although sporadic lesions [illegible] observed in the [illegible] there were no obvious differen[illegible], either in the [illegible] affected or lesion severity, [illegible] 1792 t[illegible] animals. There were n[illegible] histo[illegible] in AN-1782-immunized animals compared to PBS-treated or untreated animals. There were also no differences in the

clinical chemistry profile between adjuvant groups and the PBS treated animals in Example 7. Although there were significant [illegible] animals treated with AN1792 and Freund's adjuvant in Example 7 relative to PBS treated animals, these type of effects are expected from Freund's adjuvant treatment and the accompanying peritonitis and do not indicate any adverse effects from AN1792 treatment. Although not part of the toxicological evaluation, PDAPP mouse brain pathology was extensively examined as part of the efficacy endpoints. No sign of treatment related adverse effect on brain morphology was noted in any of the studies. These results indicate that AN1792 treatment is well tolerated and at least substantially free of side effects.

XI. Prevention and Treatment of Subjects

A single-dose phase I trial is performed to determine safety. A therapeutic agent is administered in increasing dosages to different patients starting from about 0.01 the level of presumed efficacy, and increasing by a factor of three until a level of about 10 times the effective mouse dosage is reached.

A phase II trial is performed to determine [illegible] suitable patients score [illegible] Other [illegible] are likely to survive the duration of the study and lack complicating issues such as use of concomitant medications [illegible] MMSE, and the ADAS, which is a comprehensive scale for evaluating patients with Alzheimer's Disease status and

function. These psychometric scales provide a measure of progression of the Alzheimer's condition. Suitable [illegible] Disease progression can also be monitored by MRI. Blood profiles of patients can also be monitored including assays of immunogen-specific antibodies and T-cells responses.

Following baseline measures, patients begin receiving treatment. They are randomized and treated with either therapeutic agent or placebo in a blinded fashion. Patients are monitored at least every six months. Efficacy is determined by a significant reduction in progression of a treatment group relative to a placebo group.

A second phase II trial is performed to evaluate conversion of patients from non-Alzheimer's Disease early memory loss, sometimes referred to as age-associated memory impairment (AAMI), to probable Alzheimer's disease as defined as by ADRDA criteria. Patients with high risk for conversion to Alzheimer's Disease are selected from a non-clinical population by screening reference populations for early signs of memory loss or other difficulties associated with pre-Alzheimer's symptomatology, a family history of Alzheimer's Disease, genetic risk factors, age, sex, and other features found to predict high-risk for Alzheimer's Disease. Baseline scores on suitable metrics including the MMSE and the ADAS together with [illegible]

[illegible] for each [illegible] to probable Alzheimer's Disease as defined by ADRDA criteria at the end of the observ[illegible]

XII. General Materials and Methods

[illegible]

Mice were bled by making a small nick in the tail vein and collecting about 200 μl of blood into a microfuge tube. Guinea pigs were bled by first shaving the back hock area and then using an 18 gauge needle to nick the metatarsal vein and collecting the blood into microfuge tubes. Blood was allowed to clot for one hr at room temperature (RT), vortexed, then centrifuged at 14,000 x g for 10 min to separate the clot from the serum. Serum was then transferred to a clean microfuge tube and stored at 4° C until titered.

Antibody titers were measured by ELISA. 96-well microtiter plates (Costar EIA plates) were coated with 100 μl of a solution containing either 10 μg/ml either Aβ42 or SAPP or other antigens as noted in each of the individual reports in Well Coating Buffer (0.1 M sodium phosphate, pH 8.5, 0.1% sodium azide) and held overnight at RT. The wells were aspirated and sera were added to the wells starting at a 1/100 dilution in Specimen Diluent (0.014 M sodium phosphate, pH 7.4, 0.15 M NaCl, 0.6% bovine serum albumin, 0.05% thimerosal). Seven serial dilutions of the samples were made directly in the plates in three-fold steps to reach a final dilution of 1/218,700. The dilutions were incubated in the [illegible] Specimen Diluent and incubated for one hr at RT. Plates were again washed four times in PBS, Tween 20. To develop the chromogen, 100 μl of Slow TMB (3,3',5,5'-tetramethyl benzidine [illegible] addition of 25 μl of 2 N H_2SO_4. The color intensity was then read on a Molecular Devices Vmax at (450 nm - 650 nm).

Titers were defined as the reciprocal of the dilution of serum giving one half the maximum OD. Maximal OD was generally taken from an [illegible] cases with very high titers, in which case a higher initial dilution was necessary to establish the maximal OD. If the 50% point fell between two dilutions, a linear extrapolation was made to calculate the final titer. To calculate geometric mean antibody titers, titers less than 100 were arbitrarily assigned a titer value of 25.

2. Lymphocyte proliferation assay

Mice were anesthetized with isoflurane. Spleens were removed and rinsed twice with 5 ml PBS containing 10% heat-inactivated fetal bovine serum (PBS-FBS) and then homogenized in a 50 μ Centricon unit (Dako A/S, Denmark) in 1.5 ml PBS-FBS for 10 sec at 100 rpm in a Medimachine (Dako) followed by filtration through a 100 μ pore size nylon mesh. Splenocytes were washed once with 15 ml PBS-FBS, then pelleted by centrifugation at 200 x g for 5 min. Red blood cells were lysed by resuspending the pellet in 5 mL buffer containing 0.15 M NH_4Cl, 1 M $KHCO_3$, 0.1 M NaEDTA, pH 7.4 for five min at RT. Leukocytes were then washed as above. Freshly isolated spleen cells (10^5 cells per well) were cultured in triplicate [illegible] also added at doses ranging from 5 μM to 0.18 μM in four steps. Cells in control wells were cultured with Concanavalin [illegible] Heights IL). Cells were then harvested onto UniFilter plates

and counted in a Top Count Microplate Scintillation Counter (Packard Instruments, Downers Grove, IL). Results are [illegible] incorporated into insoluble macromolecules.

4. Brain Tissue Preparation

After euthanasia, the brains were removed and one hemisphere was prepared for immunohistochemical analysis, while three brain regions (hippocampus, cortex and cerebellum) were dissected from the other hemisphere and used to measure the concentration of various $A\beta$ proteins and APP forms using specific ELISAs (Johnson-Wood et al., supra).

Tissues destined for ELISAs were homogenized in 10 volumes of ice-cold guanidine buffer (5.0 M guanidine-HCl, 50 mM Tris-HCl, pH 8.0). The homogenates were mixed by gentle agitation using an Adams Nutator (Fisher) for three to four hr at RT, then stored at -20°C prior to quantitation of $A\beta$ and APP. Previous experiments had shown that the analytes were stable under this storage condition, and that synthetic $A\beta$ protein (Bachem) could be quantitatively recovered when spiked into homogenates of control brain tissue from mouse littermates (Johnson-Wood et al., supra).

5. [illegible]

The brain homogenates were [illegible] with ice-cold Casein Diluent (0.25% casein, PBS, 0.05% sodium azide, 20 μg/ml aprotinin, 5 mM EDTA pH 8.0, [illegible]) and [illegible]

[illegible] were prepared [illegible] bovine serum albumin (BSA) in the final composition. The

"total" Aβ sandwich ELISA utilizes monoclonal antibody (mAβ) 266, specific for amino acids 13-28 of Aβ (Seubert, et al.) [illegible] for amino acids 1-5 of Aβ (Johnson-Wood, et al), as the reporter antibody. The 3D6 mAβ does not recognize secreted APP or full-length APP, but detects only Aβ species with an amino-terminal aspartic acid. This assay has a lower limit of sensitivity of ~50 ρg/ml (11 ρM) and shows no cross-reactivity to the endogenous murine Aβ protein at concentrations up to 1 ng/ml (Johnson-Wood et al., *supra*).

The Aβ1-42 specific sandwich ELISA employs mAβ 21F12, specific for amino acids 33-42 of Aβ (Johnson-Wood, et al.), as the capture antibody. Biotinylated mAβ 3D6 is also the reporter antibody in this assay which has a lower limit of sensitivity of about 125 ρg/ml (28 ρM, Johnson-Wood et al.). For the Aβ ELISAs, 100 μl of either mAβ 266 (at 10 μg/ml) or mAβ 21F12 at (5 μg/ml) was coated into the wells of 96-well immunoassay plates (Costar) by overnight incubation at RT. The solution was removed by aspiration and the wells were blocked by the addition of 200 μl of 0.25% human serum albumin in PBS buffer for at least 1 hr at RT. Blocking solution was removed and the plates were stored desiccated at 4°C until used. The plates were rehydrated with Wash Buffer [Tris-buffered saline (0.15 M NaCl, 0.01 M Tris-HCl, pH 7.5), plus 0.05% Tween 20] prior to use. The samples and standards were [illegible] and incubated in the wells [illegible] horseradish peroxidase conjugate, (Avidin-HRP obtained from Vector, Burlingame, CA [illegible] enzymatic reaction was stopped by the addition of 25 μl 2 N

H_2SO_4. The reaction product was quantified using a Molecular [illegible]

6. Measurement of APP Levels

Two different APP assays were utilized. The first, designated APP-α/FL, recognizes both APP-alpha (α) and full-length (FL) forms of APP. The second assay is specific for APP-α. The APP-α/FL assay recognizes secreted APP including the first 12 amino acids of Aβ. Since the reporter antibody (2H3) is not specific to the α-clip-site, occurring between amino acids 612-613 of APP695 (Esch et al., *Science* 248, 1122-1124 (1990)); this assay also recognizes full length APP (APP-FL). Preliminary experiments using immobilized APP antibodies to the cytoplasmic tail of APP-FL to deplete brain homogenates of APP-FL suggest that approximately 30-40% of the APP-α/FL APP is FL (data not shown). The capture antibody for both the APP-α/FL and APP-α assays is mAβ 8E5, raised against amino acids 444 to 592 of the APP695 form (Games et al., *supra*). The reporter mAβ for the APP-α/FL assay is mAβ 2H3, specific for amino acids 597-608 of APP695 (Johnson-Wood et al., *supra*) and the reporter antibody for the APP-α assay is a biotinylated derivative of [illegible]

[illegible]

Recombinant secreted [illegible] was used as the reference [illegible] for the APP-α assay and the APP-α/FL assay (Esch et al., [illegible] M guanidine [illegible]

[illegible]

Specimen Diluent containing 0.5 M guanidine. Diluted

homogenates were then centrifuged at 16,000 x g for 15 seconds [illegible] in duplicate aliquots and incubated for [illegible] hr at RT. The biotinylated reporter antibody 2H3 or 16H9 was incubated with samples for 1 hr at RT. Streptavidin-alkaline phosphatase (Boehringer Mannheim), diluted 1:1000 in specimen diluent, was incubated in the wells for 1 hr at RT. The fluorescent substrate 4-methyl-umbelliphenyl-phosphate was added for a 30-min RT incubation and the plates were read on a Cytofluor tm 2350 fluorimeter (Millipore) at 365 nm excitation and 450 nm emission.

7. Immunohistochemistry

Brains were fixed for three days at 4°C in 4% paraformaldehyde in PBS and then stored from one to seven days at 4°C in 1% paraformaldehyde, PBS until sectioned. Forty-micron-thick coronal sections were cut on a vibratome at RT and stored in cryoprotectant (30% glycerol, 30% ethylene glycol in phosphate buffer) at -20°C prior to immunohistochemical processing. For each brain, six sections at the level of the dorsal hippocampus, each separated by consecutive 240 μm intervals, were incubated overnight with one of the following antibodies: (1) a biotinylated anti-Aβ [illegible] speci[illegible] [illegible] dilu[illegible] [illegible]

[illegible] 1:500 with 0.25% [illegible] X-100 and 1% [illegible] serum, in Tris-buffered saline, pH 7.4 (TBS); or (4) a mAβ specific for [illegible], MAC-1 antigen, (Chemicon International) diluted 1:100 [illegible]

rat mAβ specific for CD 45 ([illegible]) diluted 1:100 with 1% [illegible]

rabbit serum in PBS or (7) a rat mAβ specific for CD 45RA [illegible] a rat monoclonal Aβ specific for CD 45RB [illegible] diluted 1:100 with 1% rabbit serum in PBS; or (9) a rat monoclonal Aβ specific for CD 45 (Pharmingen) diluted 1:100 with 1% rabbit serum in PBS; or (10) a biotinylated polyclonal hamster Aβ specific for CD3e (Pharmingen) diluted 1:100 with 1% rabbit serum in PBS or (11) a rat mAβ specific for CD3 (Serotec) diluted 1:200 with 1% rabbit serum in PBS; or with (12) a solution of PBS lacking a primary antibody containing 1% normal horse serum.

Sections reacted with antibody solutions listed in 1,2 and 6-12 above were pretreated with 1.0% Triton X-100, 0.4% hydrogen peroxide in PBS for 20 min at RT to block endogenous peroxidase. They were next incubated overnight at 4°C with primary antibody. Sections reacted with 3D6 or 8E5 or CD3e mAβs were then reacted for one hr at RT with a horseradish peroxidase-avidin-biotin-complex with kit components "A" and "B" diluted 1:75 in PBS (Vector Elite Standard Kit, Vector Labs, Burlingame, CA.). Sections reacted with antibodies specific for CD 45RA, CD 45RB, CD 45, CD3 and the PBS solution devoid of primary antibody were incubated for 1 hour at RT with biotinylated anti-rat IgG (Vector) diluted 1:75 in PBS or biotinylated anti-mouse IgG (Vector) diluted 1:75 in PBS, respectively. Sections were then reacted for one hr at RT [illegible]

[illegible] 3,3'-diaminobenzidine (DAB) at RT. [illegible] incubation with the GFAP-, MAC-1- AND MHC II-specific antibodies were pretreated with 0.6% hydrogen peroxide at RT [illegible]

[illegible] mouse IgG made in horse (Vector Laboratories; [illegible]

ABC Kit) diluted 1:200 with TBS. The sections were next [illegible] (Vector Laboratories; Vectastain Elite ABC Kit, diluted 1:1000 with TBS. Sections incubated with the MAC-1-or MHC II-specific mAβ as the primary antibody were subsequently reacted for 1 hr at RT with biotinylated anti-rat IgG made in rabbit diluted 1:200 with TBS, followed by incubation for one hr with avidin-biotin-peroxidase complex diluted 1:1000 with TBS. Sections incubated with GFAP-, MAC-1- and MHC II-specific antibodies were then visualized by treatment at RT with 0.05% DAB, 0.01% hydrogen peroxide, 0.04% nickel chloride, TBS for 4 and 11 min, respectively.

Immunolabeled sections were mounted on glass slides (VWR, Superfrost slides), air dried overnight, dipped in Propar (Anatech) and overlaid with coverslips using Permount (Fisher) as the mounting medium.

To counterstain Aβ plaques, a subset of the GFAP-positive sections were mounted on Superfrost slides and incubated in aqueous 1% Thioflavin S (Sigma) for 7 min following immunohistochemical processing. Sections were then dehydrated and cleared in Propar, then overlaid with coverslips mounted with Permount.

[illegible] through a CCD video camera and a Sony Trinitron monitor was used for quantification of the immunoreactive slides. The image of the section was stored in a video buffer and a color-

[illegible]

outlined and the total pixel area occupied by the hippocampus

was calculated. The percent amyloid burden was measured as: ([illegible] immunoreactive with mAβ 3D6) x 100. Similarly, the percent neuritic burden was measured as: (the fraction of the hippocampal area containing dystrophic neurites reactive with mAβ 8E5) x100. The C-Imaging System (Compix, Inc., Cranberry Township, PA) operating the Simple 32 Software Application program was linked to a Nikon Microphot-FX microscope through an Optronics camera and used to quantitate the percentage of the retrospenial cortex occupied by GFAP-positive astrocytes and MAC-1-and MHC II-positive microglia. The image of the immunoreacted section was stored in a video buffer and a monochrome-based threshold was determined to select and calculate the total pixel area occupied by immunolabeled cells. For each section, the retrosplenial cortex (RSC) was manually outlined and the total pixel area occupied by the RSC was calculated. The percent astrocytosis was defined as: (the fraction of RSC occupied by GFAP-reactive astrocytes) X 100. Similarly, percent microgliosis was defined as: (the fraction of the RSC occupied by MAC-1- or MHC II-reactive microglia) X 100. For all image analyses, six sections at the level of the dorsal hippocampus, each separated by consecutive 240 μm intervals, were quantitated for each animal. In all cases, the treatment status of the animals was unknown to the observer.

Although the foregoing invention has been described in detail for purposes of [illegible] their entirety for all purposes to the same extent as if each were so individually denoted.

TABLE 1

TITER AT 50% MAXIMAL O.D.

Aggreated Aß Injected mice

APP	mouse [illegible]	[illegible]01	mouse 102	mouse 103	mouse 104	mouse 105	mouse 106	mouse 107	[illegible] 108
4		[illegible]000	15000	120000	1000	15000	50000	80000	100000
6		[illegible]000	30000	55000	300	15000	15000	50000	60000
8		[illegible]000	50000	50000	400	15000	18000	50000	60000
10		[illegible]000	60000	50000	900	15000	50000	20000	40000
12		[illegible]000	60000	40000	2700	20000	70000	25000	20000

PBS Injected mice on both Immunogens at 1/100

APP	mouse 113	mouse 114	mouse115	mouse116	mouse117
6	< 4x bkg	< 4x bkg	< 4x bkg	< 4x bkg	< 4x bkg
10	5 x bkg	< 4x bkg	< 4x bkg	< 4x bkg	< 4x bkg
12	< 4x bkg	< 4x bkg	< 4x bkg	< 4x bkg	< 4x bkg

WHAT IS CLAIMED IS:

1. A pharmaceutical composition comprising an agent effective to induce an immunogenic response against Aβ in a patient, and a pharmaceutically acceptable adjuvant.

2. The pharmaceutical composition of claim 1, wherein the agent is Aβ or an active fragment thereof.

3. The pharmaceutical composition of claim 1 or 2, wherein the adjuvant comprises alum.

4. The pharmaceutical composition of claim 1 or 2, wherein the adjuvant comprises monophosphoryl lipid (MPL).

5. The pharmaceutical composition of claim 1 or 2, wherein the adjuvant comprises QS21.

[illegible], wherein the Aβ or fragment is a component of a particle.

[illegible] particle is a polylactide polyglycolide copolymer (PLPG) particle.

8. A method of preventing or treating a disease characterized by amyloid deposits in a patient, comprising:

administering an agent effective to induce an immune response against a peptide component of an amyloid deposit in the patient.

9. The method of claim 8, wherein the amyloid deposit comprises aggregated Aβ peptide.

10. The method of claim 8 or 9, wherein the patient is a human.

11. The method of any of the preceding claims, wherein the disease is Alzheimer's disease.

12. The method of any of the preceding claims, wherein the patient is asymptomatic.

the patient is under [illegible]

14. The method of any of the preceding claims, wherein the [illegible]

15. The method of any [illegible] has no known risk factors for Alzheimer's disease.

16. The method of any of the preceding claims, wherein the agent comprises Aβ peptide or an active fragment thereof.

17. The method of any of the preceding claims, wherein the agent is Aβ peptide or an active fragment thereof.

18. The method of claim 17, wherein the dose of Aβ peptide administered to the patient at least 50 μg.

19. The method of claim 17, wherein the dose of Aβ peptide administered to the patient is at least 100 μg.

20. The method of any of the preceding claims, wherein the [illegible]

21. The method of claim 20, wherein the Aβ peptide is administered in aggregated form.

22. The method of claim any of the preceding claims, wherein the immune response comprises [illegible]

23. The method of any of the preceding claims, wherein the immune response comprises T-cells that bind to the Aβ peptide as a component of an MHC I or MHC II complex.

24. The method of any one of claims 8, or 10-15 wherein agent is an antibody to Aβ which induces an immune response by binding to Aβ in the patient.

25. The method of claims 8 or 10-15, wherein T-cells are removed from the patient, contacted with Aβ peptide under conditions in which the T-cells are primed, and the primed T-cells are administered to the patient.

26. The method of any of the preceding claims, wherein the agent is administered orally, subcutaneously, intramuscularly, topically or intravenously.

27. The method of any of the preceding claims, wherein the agent is administered intramuscularly or subcutaneously.

28. The method of any of the preceding claims, further [illegible] compound reactive with [illegible], and [illegible] compound to the patient to induce the immune response.

29. The method of any one of claims 8, 10-15, 26 or 27, wherein the agent is an effective dose of a nucleic acid encoding Aβ or an active fragment thereof, whereby the nucleic acid is expressed in the patient to produce Aβ or the active fragment thereof, which induces the immune response.

30. The method of claim 29, wherein the nucleic acid is administered through the skin.

31. The method of claim 30, wherein the nucleic acid is applied to the skin by a patch.

32. The method of any of the preceding claims, further [illegible] monitoring [illegible]

33. The method of any of the preceding claims, further comprising administering an adjuvant that enhances the immune response to the Aβ peptide.

34. The method of claim 33, wherein the adjuvant and the agent are administered together as a composition.

35. The method of claim 33, wherein the adjuvant is administered before the agent.

36. The method of claim 33, wherein the adjuvant is administered after the agent.

37. The method of any one of claims 33-36, wherein the adjuvant is alum.

38. The method of any one of claims 33-36, wherein the adjuvant is MPL.

39. The method of any one of claims 33-36, wherein the adjuvant is QS21.

40. The method of any one of claims [illegible], wherein the dose of Aβ peptide is greater than 10 μg.

41. A method of preventing or treating Alzheimer's disease comprising administering an effective dose of Aβ peptide to a patient.

42. Use of Aβ peptide, or an antibody thereto, in the manufacture of a [illegible] Alzheimer's disease.

43. The use of claim 42, wherein the Aβ peptide is combined with a pharmaceutically acceptable adjuvant in the manufacture of the medicament.

44. A composition comprising Aβ or a fragment linked to a conjugate molecule that promotes delivery of Aβ to the bloodstream of a patient and/or promotes an immune response against Aβ.

45. The composition of claim 44, wherein the conjugates promotes an immune response against Aβ.

46. The composition of claim 44 or 45, wherein the conjugate is cholera toxin.

47. The composition of claim 44 or 45, wherein the conjugate is an immunoglobulin.

48. The composition of claim 44 or 45, wherein the conjugate is attenuated diphtheria toxin ([illegible]).

49. A pharmaceutical composition comprising an agent eff[illegible] patient with the proviso th[illegible] the composition [illegible] Complete Freund's adjuvant.

50. A composition comprising a viral vector encoding Aβ or a fragment thereof effective to induce an immune response against Aβ.

51. A composition of claim 50, wherein the viral vector is herpes, adenovirus, adenoassociated virus, a retrovirus, sindbis, semiliki forest virus, vaccinia or avian pox.

52. A method of assessing efficacy of an Alzheimer's treatment method in a patient, comprising

determining a baseline amount of antibody specific for Aβ peptide in tissue sample from the patient before treatment with an agent,

comparing an amount of antibody specific for Aβ peptide in the tissue sample from the patient after treatment with the agent to the baseline am[illegible]

wherein an amount of Aβ peptide-specific antibody [illegible] after the treatment that is significantly greater than the baseline amount of Aβ peptide-specific antibody indicates a positive treatment outcome.

53. The method of claim 52, wherein the amounts of [illegible]

54. The method of claim 53, wherein the amounts of antibody are measured by an ELISA assay.

55. A method of assessing efficacy of an Alzheimer's treatment method in a patient, comprising

determining a baseline amount of antibody specific for Aβ peptide in tissue sample from a patient before treatment with an agent;

comparing an amount of antibody specific for Aβ peptide in the tissue sample from the subject after treatment with the agent to the baseline amount of Aβ peptide-specific antibody,

wherein a reduction or lack of significant difference between the amount of Aβ peptide-specific antibody measured after the treatment compared to the baseline amount of Aβ peptide-specific antibody indicates a negative treatment outcome.

56. A method of assessing efficacy of an Alzheimer's treatment method in a patient, comprising

determining a control amount of antibody specific for Aβ peptide in tissue samples from a control population,

comparing an amount of antibody specific for Aβ peptide in a tissue sample from the patient after administering an agent to the control amount of Aβ peptide-specific antibody,

wherein an amount of Aβ peptide-specific antibody measured [illegible] control amount of Aβ peptide-specific antibody indicates a positive treatment outcome.

57. A method of assessing efficacy of an Alzheimer's treatment method in a patient, comprising

determining a control amount of antibody specific for Aβ peptide in tissues samples from a control population,

comparing an amount of antibody specific for Aβ peptide in a tissue sample from the patient after administering an agent to said control amount of Aβ peptide-specific antibody,

wherein a lack of significant difference between the amount of Aβ peptide-specific antibody measured after beginning said treatment compared to the control amount of Aβ peptide-specific antibody indicates a negative treatment outcome.

.58. A method of monitoring Alzheimer's disease or susceptibility thereto in a patient, comprising:

detecting an immune response against Aβ [illegible] in a sample [illegible] patient.

59. The method of claim 58, wherein the patient is being administered an agent [illegible] the future treatment regime of the patient.

60. The method of claim 59, wherein the agent is Aβ peptide.

61. The method of any one of claims 57-60, wherein the detecting comprises detecting an antibody that specifically binds to Aβ peptide.

62. The method of any one of claims 57-60, wherein the detecting comprises detecting T-cells specifically reactive with Aβ peptide.

63. A method of assessing efficacy of an Alzheimer's treatment method in a patient, comprising

determining a value for an amount of antibody specific for Aβ peptide in tissue sample from a patient who has been treated with an agent;

comparing the value with a control value determined from a population of patient experiencing amelioriation of, or freedom from, symptoms of [illegible] with the agent;

wherein a value in the patient at least equal to the control value indicates a positive response to treatment.

64. Use of Aβ peptide in monitoring treatment of Alzheimer's disease in a patient.

65. A diagnostic kit for monitoring treatment of Alzheimer's disease, comprising:

an agent that binds to antibodies specific for Aβ peptide.

66. The diagnostic kit of claim 65, further comprising labelling indicating how the kit is used for monitoring treatment of Alzheimer's disease.

FIGURE 1

TITER OF AGGREGATED Aβ_{42} INJECTED PDAPP MICE OVER TIME

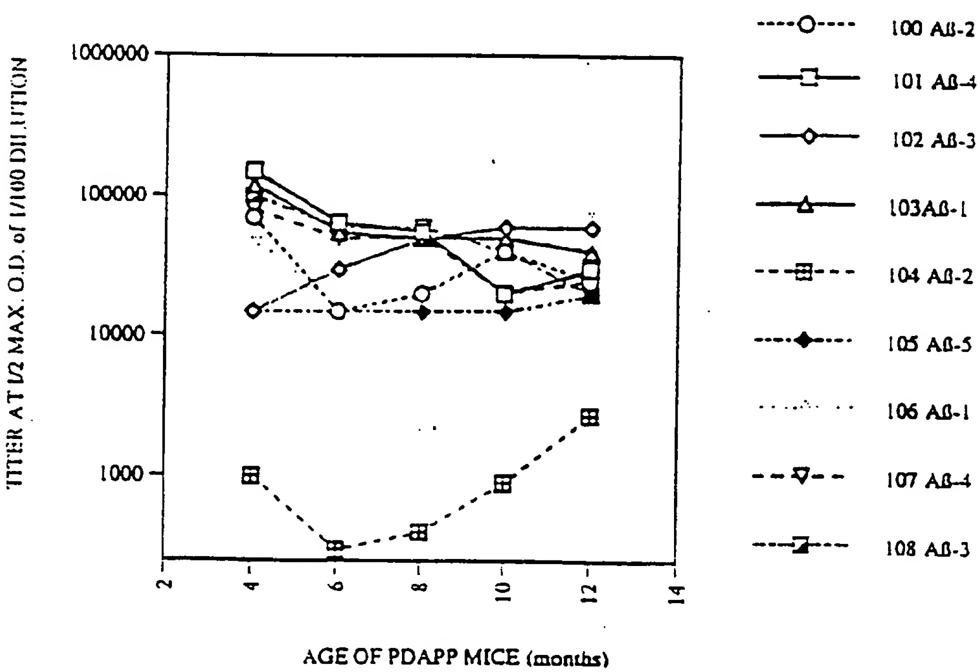


Figure 2

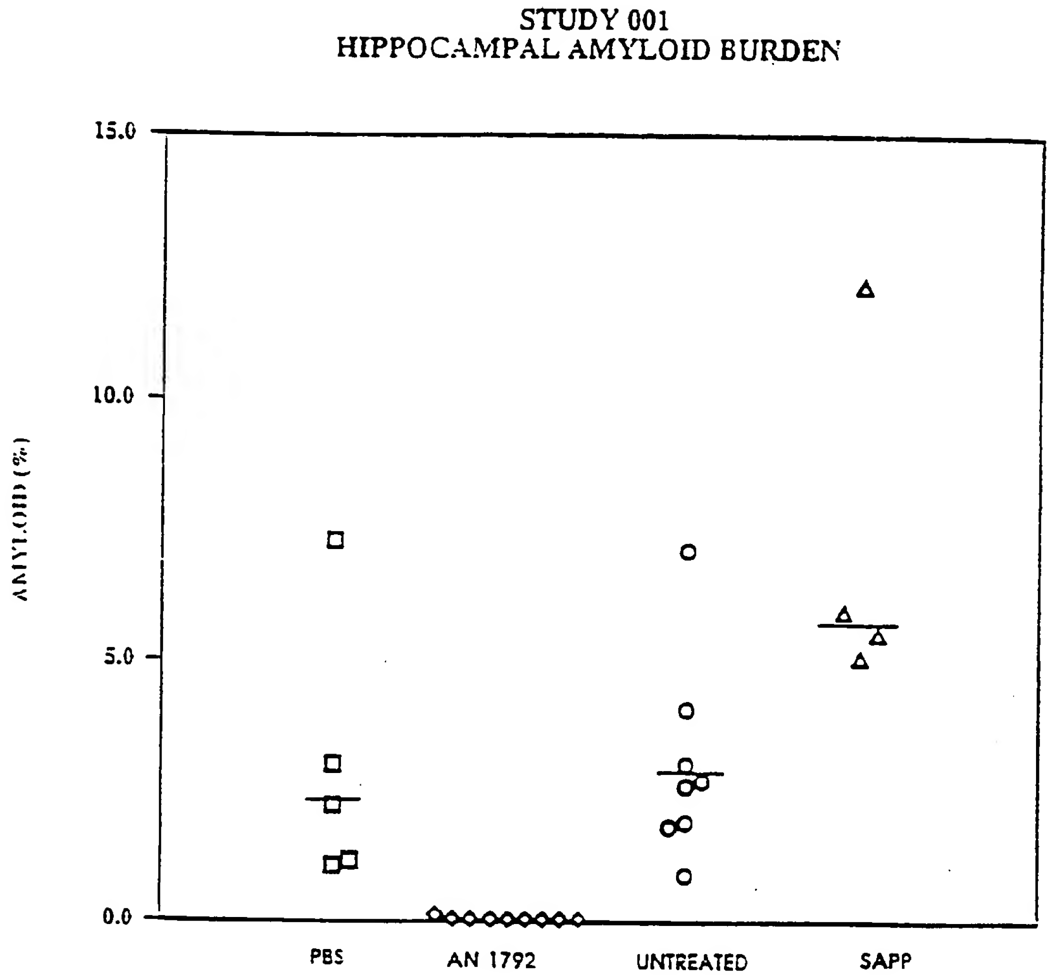

STUDY 001
HIPPOCAMPAL AMYLOID BURDEN
15.0
10.0
5.0
0.0
AMYLOID (%)
PBS
AN 1792
UNTREATED
SAPP

Figure 3

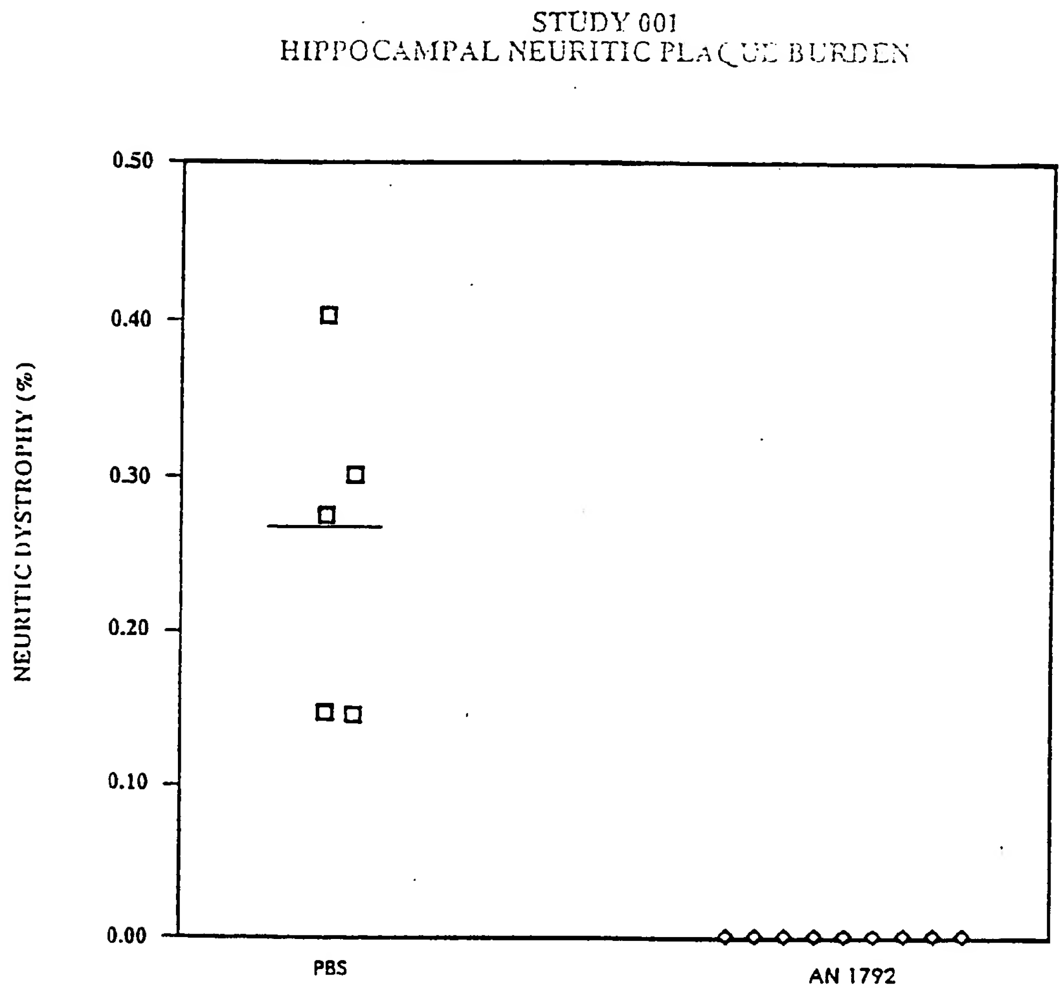

STUDY 001
HIPPOCAMPAL NEURITIC PLAQUE BURDEN
NEURITIC DYSTROPHY (%)
0.50
0.40
0.30
0.20
0.10
0.00
PBS
AN 1792

Figure 4

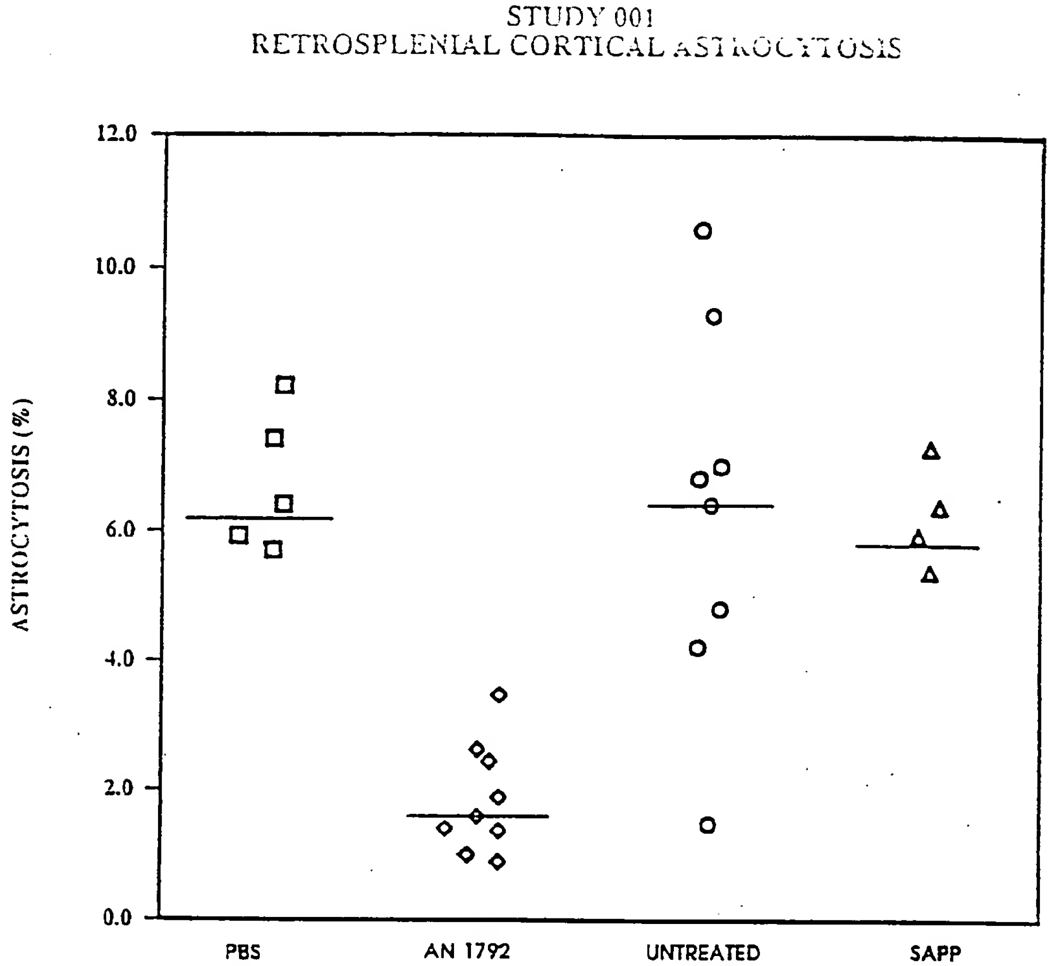

STUDY 001
RETROSPLENIAL CORTICAL ASTROCYTOSIS
ASTROCYTOSIS (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
PBS
AN 1792
UNTREATED
SAPP

Figure 5

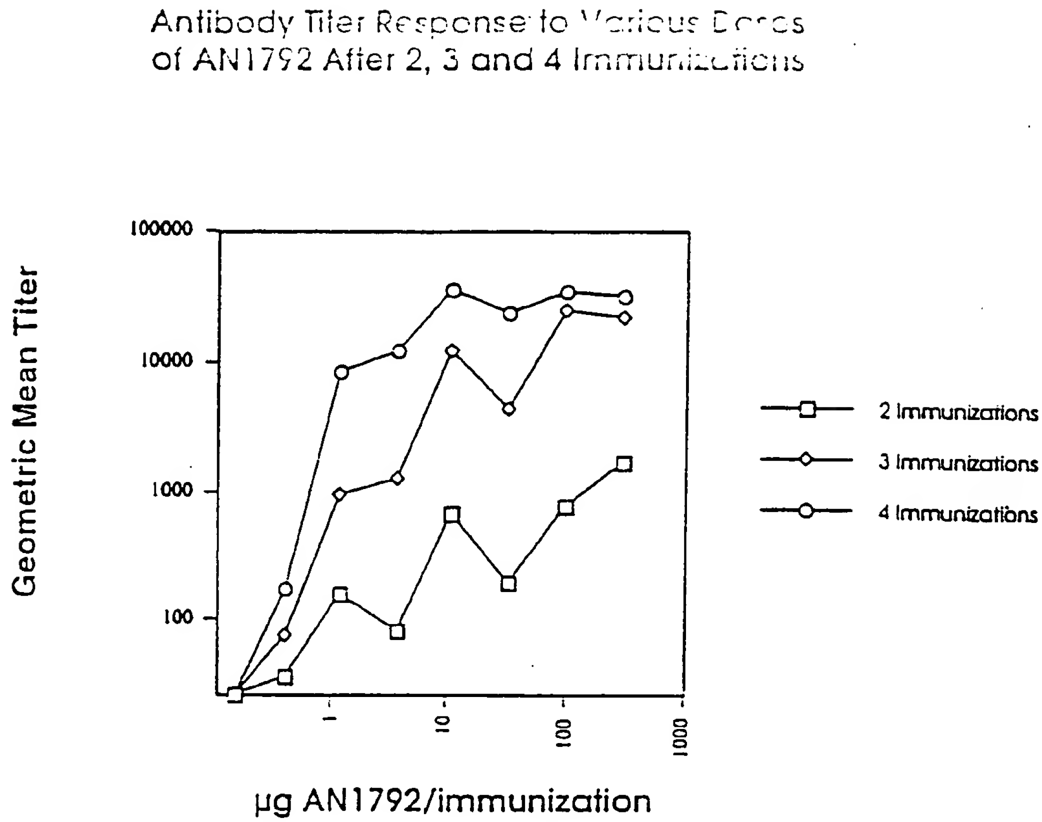

Antibody Titer Response to Various Doses
of AN1792 After 2, 3 and 4 Immunizations
Geometric Mean Titer
100000
10000
1000
100
1
10
100
1000
µg AN1792/immunization
2 Immunizations
3 Immunizations
4 Immunizations

Figure 6

Kinetics of Antibody Response to AN1792

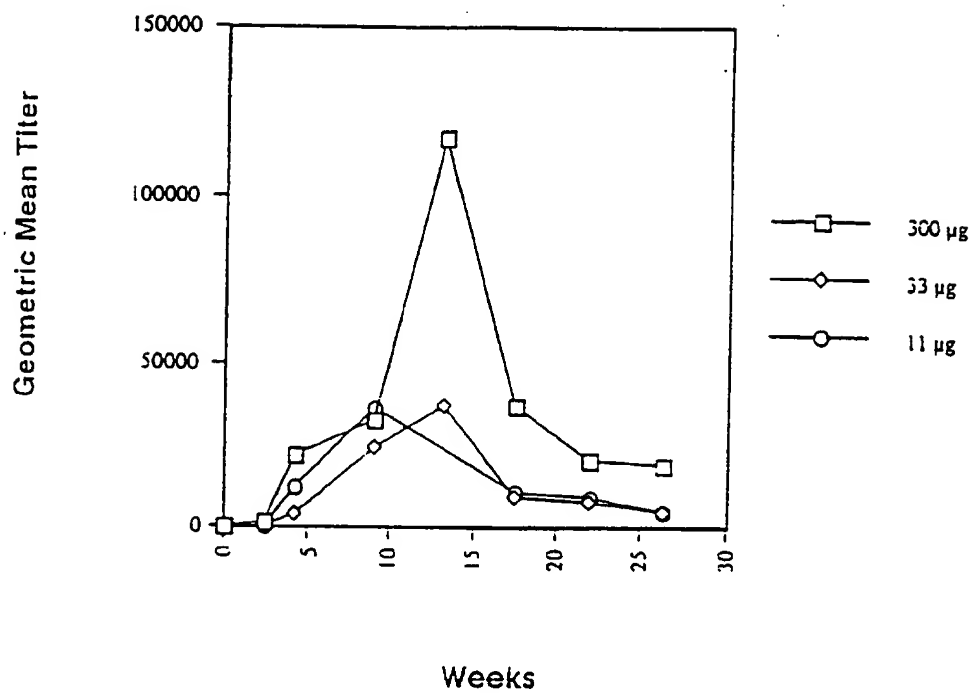


Figure 7

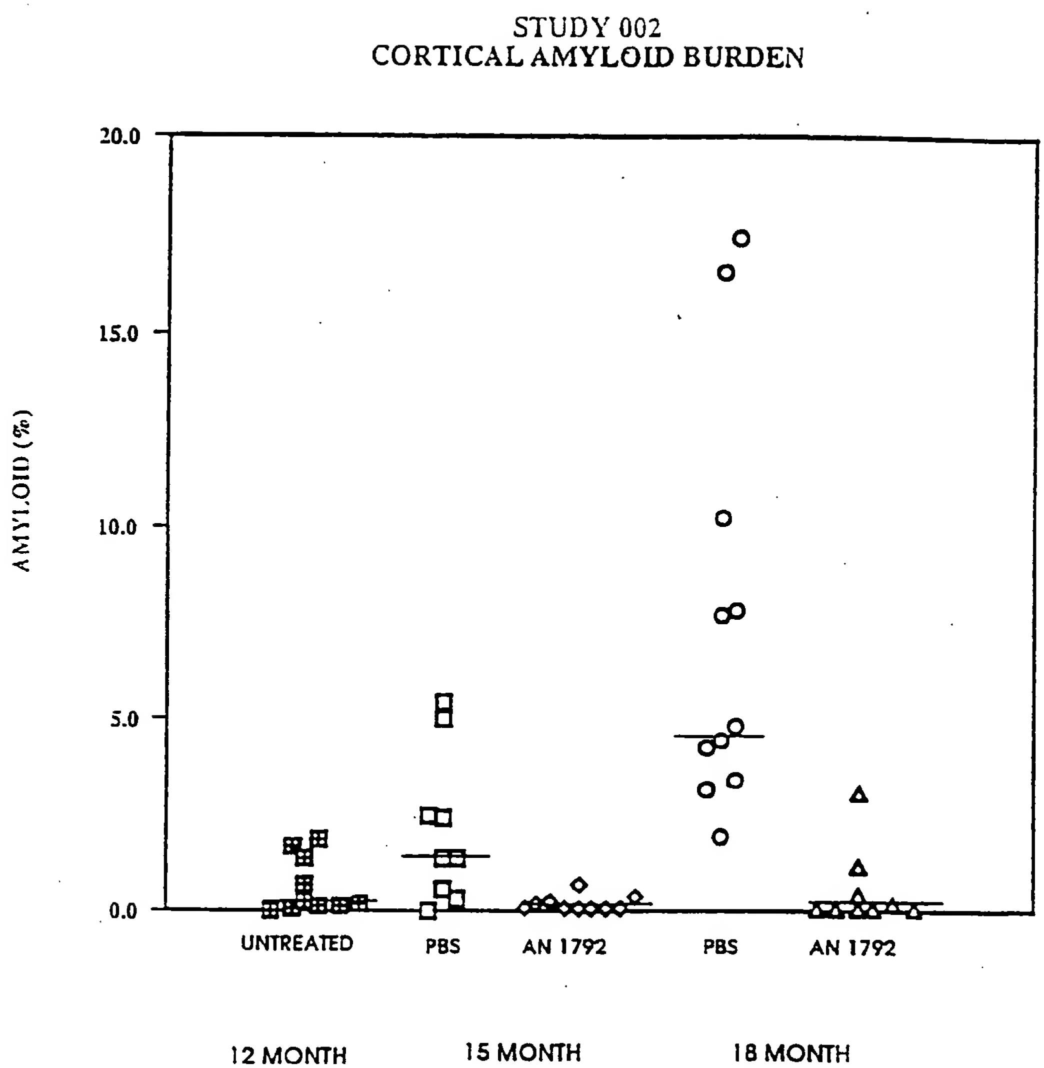

STUDY 002
CORTICAL AMYLOID BURDEN
20.0
15.0
10.0
5.0
0.0
AMYLOID (%)
UNTREATED
PBS
AN 1792
PBS
AN 1792
12 MONTH
15 MONTH
18 MONTH

Figure 8

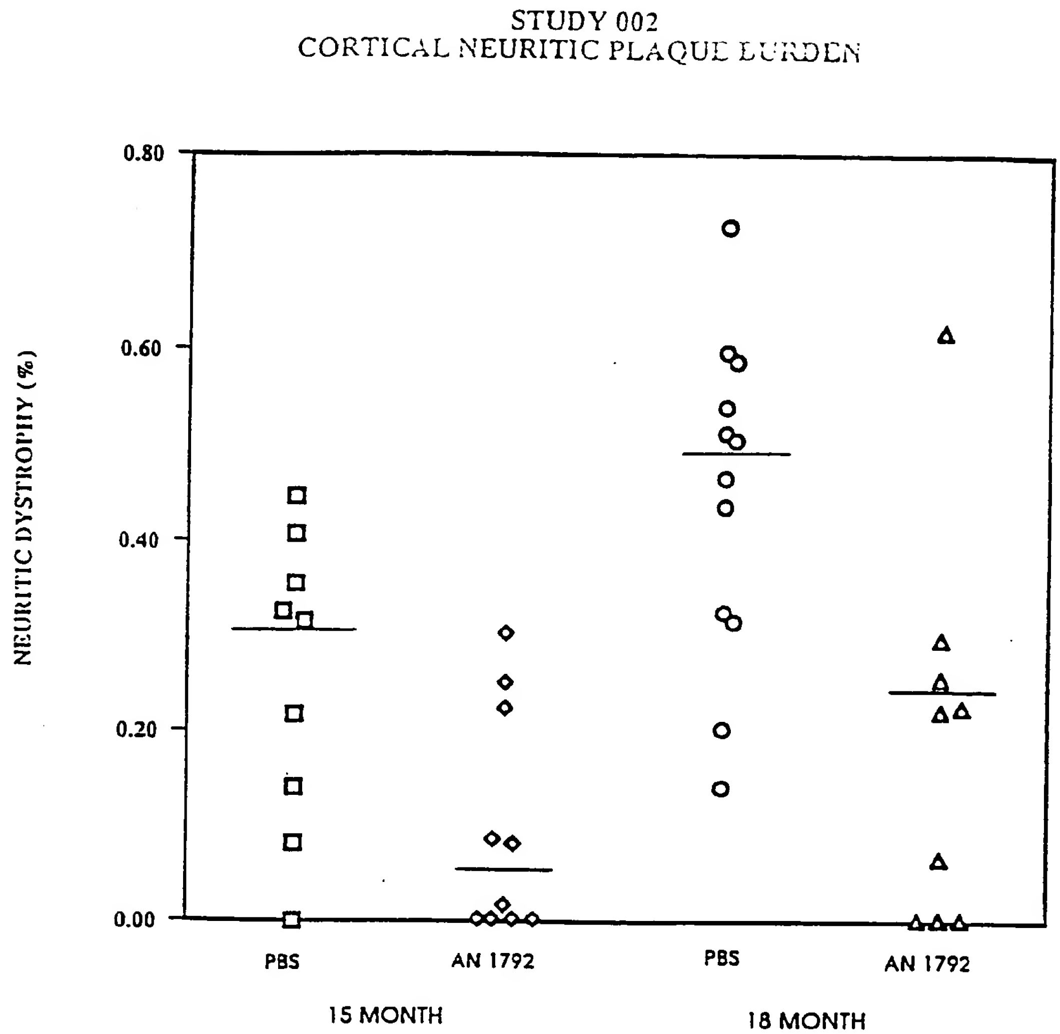

STUDY 002
CORTICAL NEURITIC PLAQUE BURDEN
NEURITIC DYSTROPHY (%)
0.80
0.60
0.40
0.20
0.00
PBS
AN 1792
PBS
AN 1792
15 MONTH
18 MONTH

Figure 9

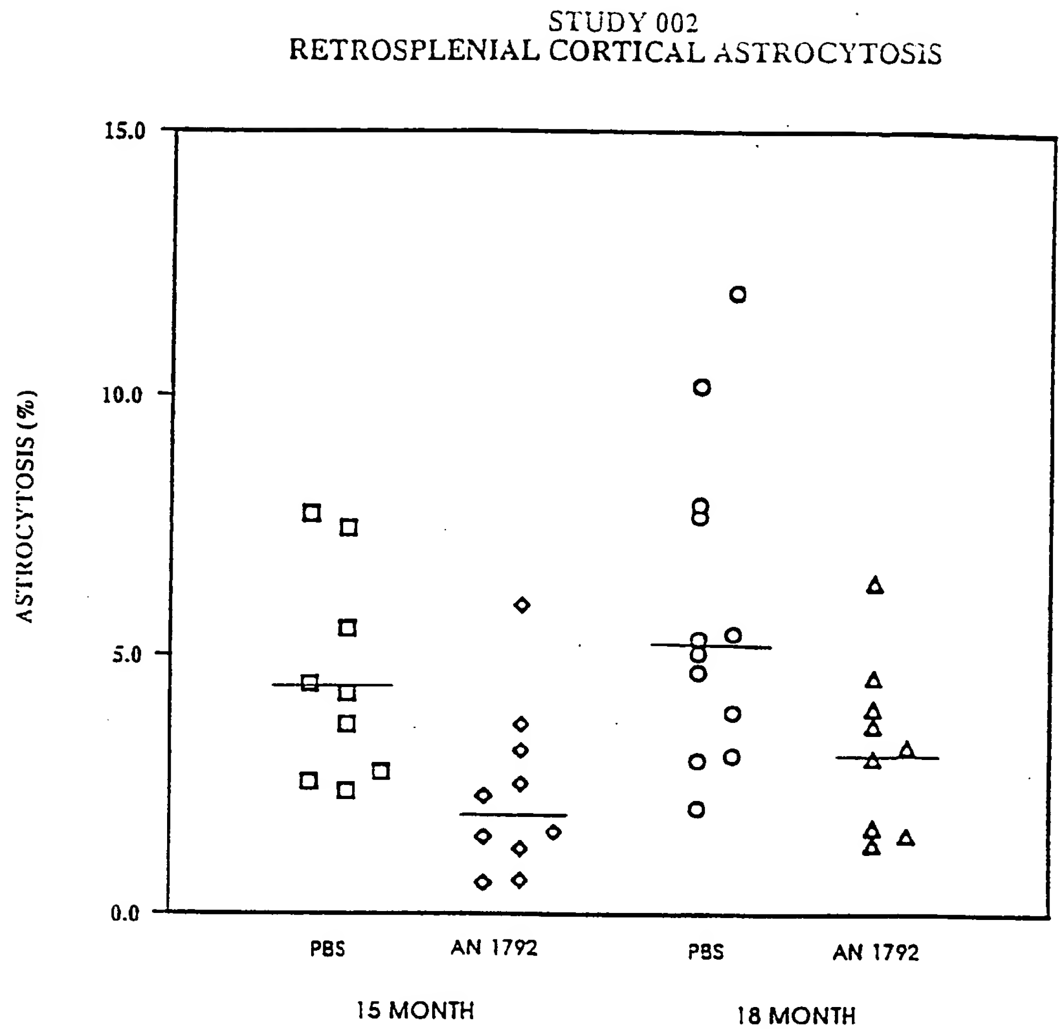
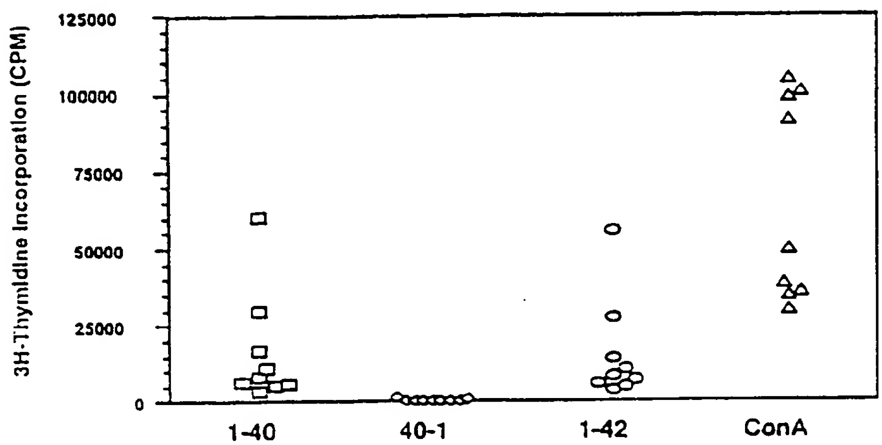

STUDY 002
RETROSPLENIAL CORTICAL ASTROCYTOSIS
15.0
10.0
5.0
0.0
ASTROCYTOSIS (%)
PBS
AN 1792
PBS
AN 1792
15 MONTH
18 MONTH

Figure 10

Study 002: Splenocyte Proliferation Assay

AN1792-Treated Group



PBS-Treated Group

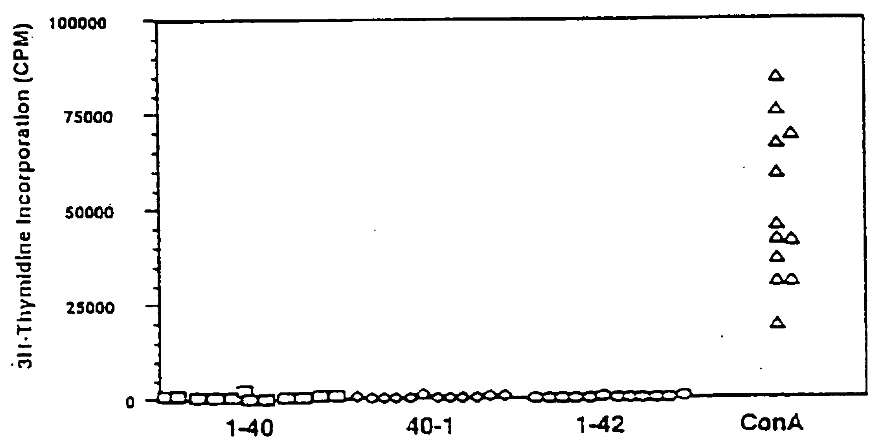


Figure 11

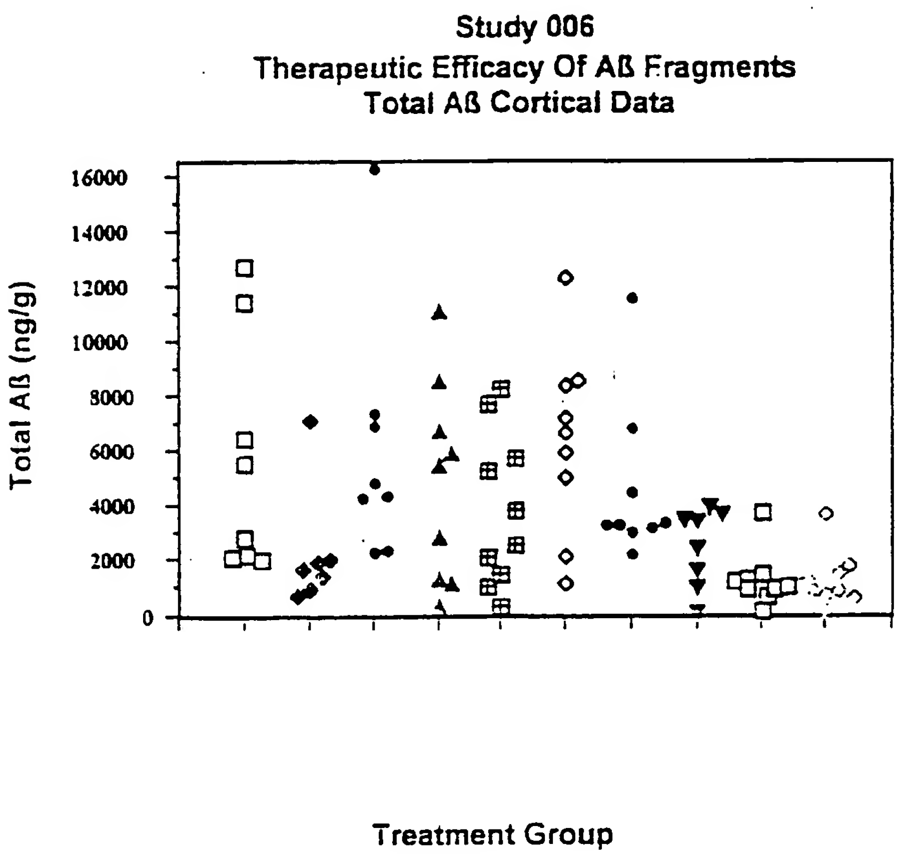

Study 006
Therapeutic Efficacy Of Aß Fragments
Total Aß Cortical Data
16000
14000
12000
10000
8000
6000
4000
2000
0
Total Aß (ng/g)
Treatment Group

Figure 12

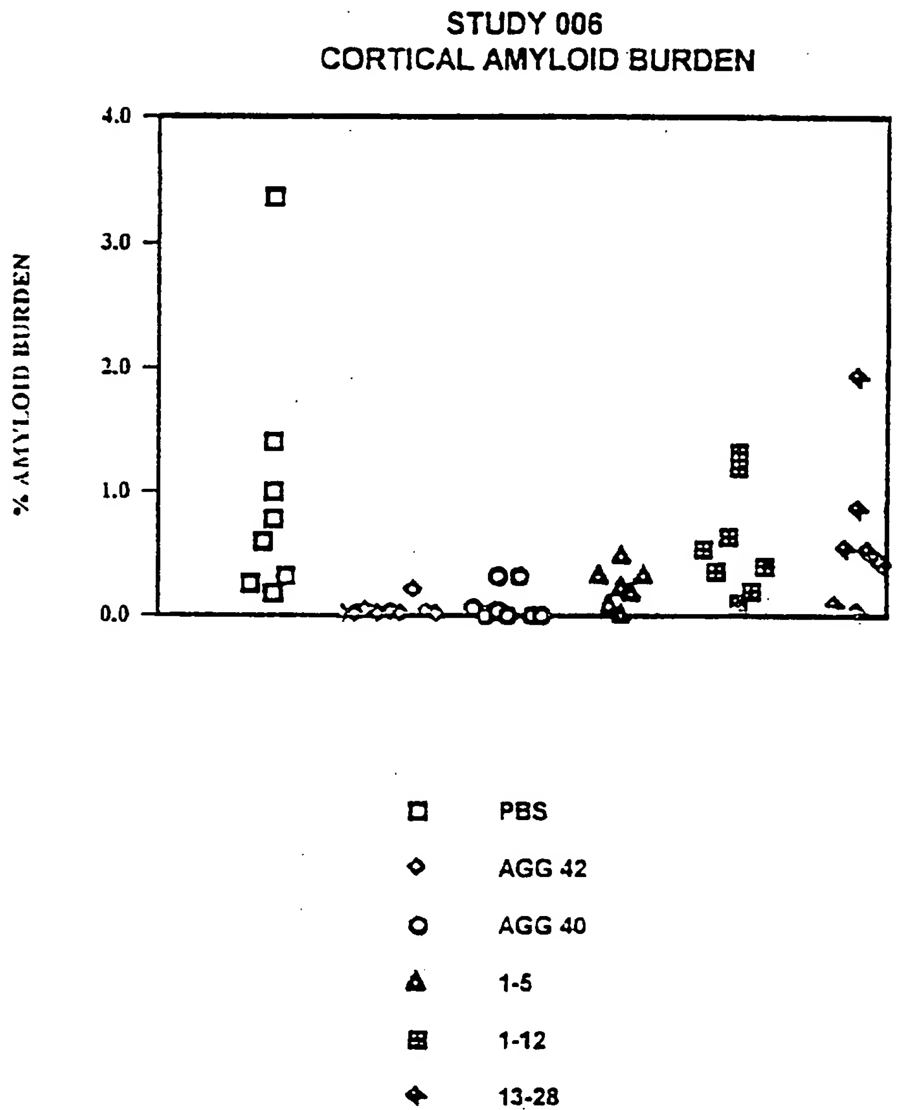

STUDY 006
CORTICAL AMYLOID BURDEN
% AMYLOID BURDEN
4.0
3.0
2.0
1.0
0.0
PBS
AGG 42
AGG 40
1-5
1-12
13-28

Figure 13

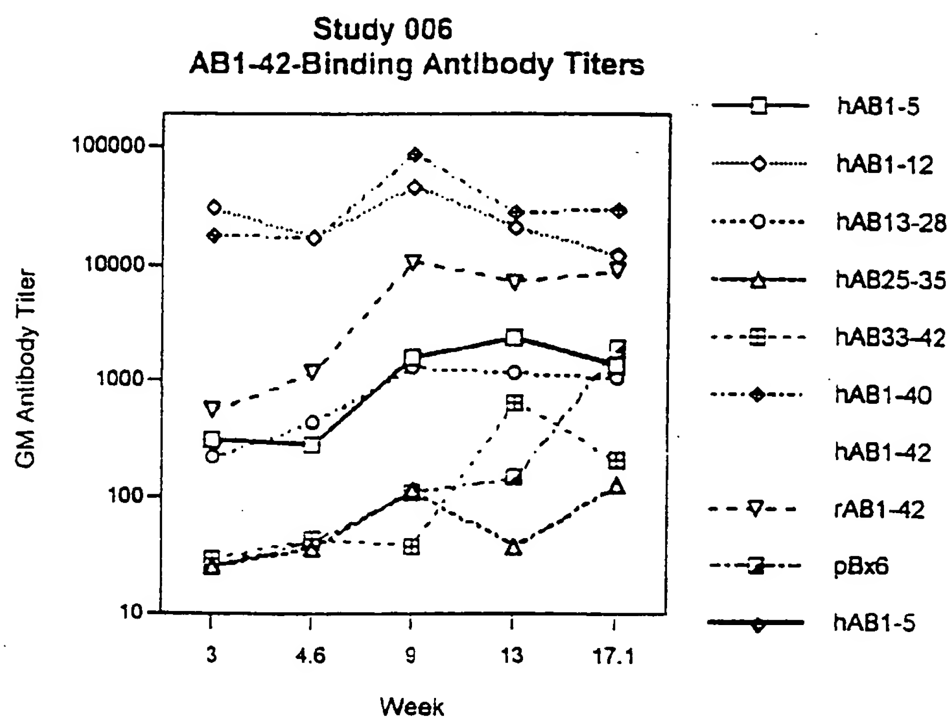

Study 006
AB1-42-Binding Antibody Titers
GM Antibody Titer
100000
10000
1000
100
10
3
4.6
9
13
17.1
Week
hAB1-5
hAB1-12
hAB13-28
hAB25-35
hAB33-42
hAB1-40
hAB1-42
rAB1-42
pBx6
hAB1-5

Figure 14

Antibody Responses to AN1792 With Different Adjuvants

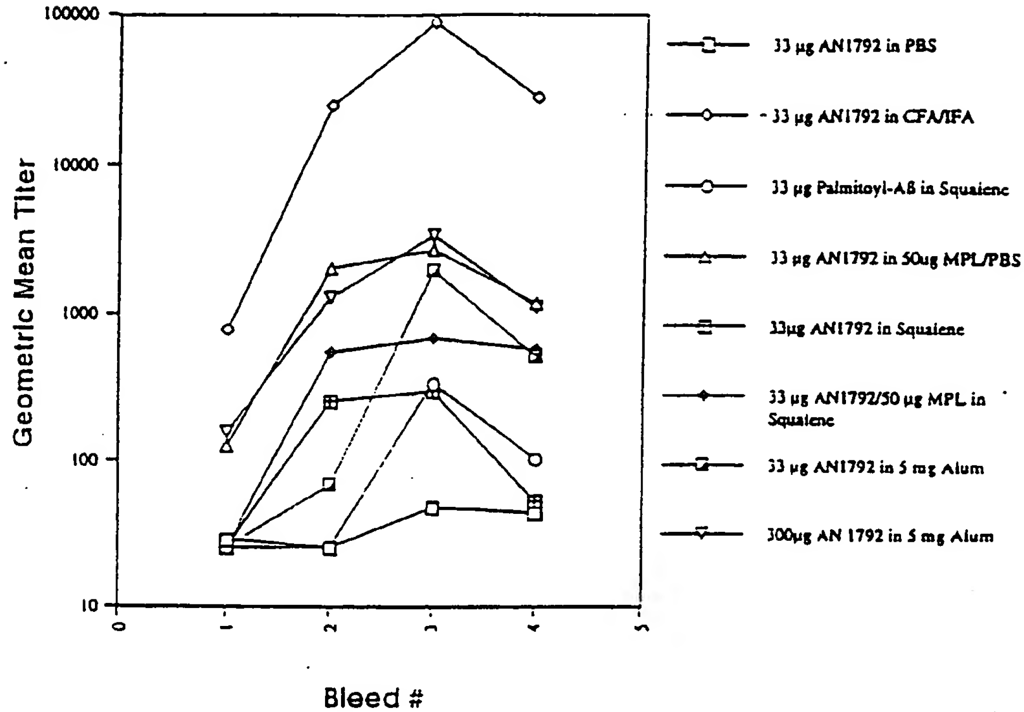


Figure 15

CORTEX

PBS Control		[illegible]		2mg Alum 100 µg AN1528		50 µg MPL 100 µg AN1528		25 µg QS21 100 µg AN1528	
624-165	272	764-181	3470	660-083	295	643-105	385	615-128	1257
625-166	1802	765-182	171	661-084	3180	644-106	3040	616-129	361
626-167	52	766-183	91	662-085	2480	645-107	2403	617-130	1008
633-168	4696	767-184	5692	663-086	3014	654-108	1741	636-131	3290
534-169	3090	768-185	1353	664-087	5670	655-109	3053	637-132	2520
571-170	2417	771-186	1153	665-088	5978	656-110	5990	638-133	3880
572-171	2840	772-187	3800	693-089	1620	678-111	3380	744-134	627
629-172	3320	780-188	3740	694-090	35	679-112	1230	745-135	58
630-173	1833	843-189	163	695-091	3400	704-114	2680	746-136	2810
631-174	416	844-190	122	697-092	2630	705-115	78	747-137	1509
792-175	129	845-191	427	698-093	983	706-116	1290	769-138	1788
793-176	2559	846-192	2574	699-094	5327	729-117	3180	770-139	988
794-177	289	887-193	453	701-095	1882	730-118	1833	773-140	1199
732-178	179	888-194	2996	702-096	1849	731-119	4590	774-141	339
733-179	1329	889-195	1075	703-097	2239	736-120	1112	775-142	402
734-180	5685			739-098	806	737-121	1633	776-143	537
				740-099	5303	757-122	992	840-144	1119
				741-100	459	758-123	4682	841-145	194
				800-103	154	808-124	765	821-146	1259
				801-104	852	809-125	244	822-147	5413
						810-126	22	823-148	2233
Median	1817	Median	1153	Median	2051	Median	1741	Median	1199
p Value (M-W)		p Value (M-W)		p Value (M-W)		p Value (M-W)		p Value (M-W)	
Mean	1931	Mean	1825	Mean	2407	Mean	2140	Mean	1552
St. Dev.	1718	St. Dev.	1769	St. Dev.	1913	St. Dev.	1659	St. Dev.	1384
% CV	89	% CV	97	% CV	79	% CV	78	% CV	88
p Value (t Test)		p Value (t Test)		p Value (t Test)		p Value (t Test)		p Value (t Test)	
	n=16		n=15		n=20		n=21		n=21

CFA/IFA 100 µg AN1792		5 µg Thimerosal/PBS 10 µg AN1792		2 mg Alum 100 µg AN1792		50 µg MPL 100 µg AN1792		25 µg QS21 100 µg AN1792	
639-066	893	635-149	1337	610-001	432	646-023	2002	627-045	91
640-068	508	669-150	4644	611-002	1012	647-024	147	628-046	3397
641-070	440	670-151	6335	612-003	3607	648-025	1304	631-049	3702
642-071	467	673-152	3700	613-004	508	649-026	34	632-050	1776
690-072	42	674-153	2750	620-005	465	650-027	980	567-052	1832
691-073	2491	676-154	1687	621-006	16	724-028	1282	568-053	2023
692-074	121	681-156	185	622-007	28	726-030	1966	566-054	189
795-075	137	682-157	8031	623-008	217	727-031	733	587-055	891
796-076	122	683-158	3450	708-009	2738	720-032	2563	588-056	240
797-077	475	754-159	157	709-010	327	721-033	5583	589-057	110
748-078	500	755-160	6857	710-011	1609	802-034	113	712-059	3311
749-079	78	756-161	482	716-012	1606	803-035	671	825-061	1009
750-080	1207	805-162	524	784-014	3890	804-036	31	826-062	18185
751-081	1351	806-163	397	785-015	1614	811-037	613	827-063	73
761-082	68	807-164	234	786-016	265	812-038	332	828-064	78
				787-017	3102	813-039	1454	837-065	1051
				788-018	1617	814-040	2441	838-066	270
				789-019	1474	833-041	742	839-067	371
				815-020	424	834-042	40		
				816-021	1375	836-044	807		
				817-022	2323				
Median	475	Median	1687	Median	1375	Median	774	Median	950
p Value (M-W)	0.0481	p Value (M-W)		p Value (M-W)	0.5000	p Value (M-W)	0.1710	p Value (M-W)	0.4078
Mean	637	Mean	2716	Mean	1394	Mean	1192	Mean	2199
St. Dev.	655	St. Dev.	2685	St. Dev.	1166	St. Dev.	1299	St. Dev.	4187
% CV	103	% CV	99	% CV	84	% CV	109	% CV	190
p Value (t Test)	0.0106	p Value (t Test)		p Value (t Test)	0.2650	p Value (t Test)	0.1506	p Value (t Test)	0.8131
	n=15		n=16		n=21		n=21		n=18

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/25386

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :A61K 38/00, 38/28, 9/26, 33/06
US CL :424/88, 92, 570, 698; 514/ 2, 4, 21
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 424/88, 92, 570, 698; 514/ 2, 4, 21

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

STN: COMPOUNDS AND METHODS OF USE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 526 511 B1 (MCMICHAEL) 28 MAY 1997, see entire document	1-66
Y	Chemical Abstracts, volume 120, number 8, issued 21 February 1994, Prieels et al, "Synergistic adjuvants for vaccines"page 652, column 1, abstract no. 86406t, PCT Int. Appl. WO 94 00,153, 06 January 1994, see entire abstract	1-66

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
18 MARCH 1999	08 APR 1999

Name and mailing address of the ISA/US	Authorized officer
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